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THE EFFECT OF CLIMATE IN BRITISH COLUMBIA ON THE CHEMICAL COMPOSITION OF TOMATOES[1]

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Consumers today are interested, and rightly so, in the food values of horticultural crops. While much work has been done on soil conditions and manurial factors which influence growth, definite information on the influence of climate or locality on food values appears to be relatively scarce.

Tomatoes are an important horticultural crop in British Columbia, both for the fresh market and for the canning industry. In view of their importance it was decided to note, on the one hand, whether the food value of tomatoes varied with different varieties, and on the other hand, whether the food value of the same variety varied with different localities.

For this purpose the following experiments were carried out in the Plant Nutrition Laboratory of the Horticulture Department at the University of British Columbia, as part of a series in a nutritional study programme.

MATERIALS AND METHODS

To determine the effect of *variety* on the food value, samples of vine-ripened fruit from 10 varieties of tomatoes which had been grown in the horticultural plots of the University under similar conditions were brought into the laboratory. Characteristics of the fresh fruit, such as size, colour, uniformity, shape, thickness of cell walls, number of locules, and juiciness were recorded. Dry weights, ash, total sugars, pH of juice, and vitamin C content were also determined. The varieties used were as follows:

Rutgers, Bestal, Seedling Selection 4037100, Valiant, Harkness,

Early Baltimore, Bonny Best, Bonton, Earlianna, and Jan Rue.

In order to ascertain the effect of *climate and locality* on food values of tomatoes, samples of commercially canned fruit of the same variety (Earlianna) were obtained from 5 leading tomato growing areas in British Columbia and 1 from Ontario. With regard to the Ontario sample, little can be said except that it is a brand of good quality on the British Columbia market and meeting B.C. competition. In the British Columbia districts the climate varies from a cool, temperate, coastal climate to dry, desert conditions where irrigation is practised.

The contents of the cans from these areas were examined for drained weight, colour, etc., as usually practised in routine inspection of canned goods, as well as for pH, total sugars, dry weight, ash, total nitrogen,

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phosphorus, potash and vitamin C. The pH readings were made with a Beckman pH meter. For dry weight determinations a vacuum oven was used. Total sugars were determined by the Lane and Enyon copper reduction method (4). Ashing was done in an electrical muffle furnace. Total nitrogen was determined by the Kjeldahl method A.O.A.C. (5). The Briggs colorimetric method of determining phosphorus was employed (2). Potash was determined by the Sherrill method (6) and vitamin C determined as ascorbic acid by the chemical method of Bessey and King (1).

Table 1 gives an index to the climatic conditions in the areas where the tomatoes were grown.

TABLE 1.—AVERAGE MONTHLY WINTER AND SUMMER MEAN TEMPERATURE, PRECIPITATION, AND HOURS OF SUNSHINE FOR THE PERIOD 1930–38 IN THE TOMATO-GROWING AREAS IN BRITISH COLUMBIA (3)

Locality	Mean temperature, degrees Fahrenheit		Precipitation, inches		Hours of bright sunshine	
	April-Sept.	Oct.-Mar.	April-Sept.	Oct.-Mar.	April-Sept.	Oct.-Mar.
A	59.0	42.2	2.27	7.10	230	77.7
B	59.5	37.0	1.23	1.86	231	79.8
C	59.8	33.0	1.11	1.43	239	84.1
D	62.0	33.5	0.90	0.76	238	101.2
E	63.5	33.3	0.68	0.76	249	99.9
F	64.5	35.8	0.56	0.77	254	99.8

In comparing the districts it is noted that District A has a mild, uniform climate. The winters are relatively warm, with high precipitation and low in hours of sunshine. The summers are cool, precipitation higher and hours of bright sunshine slightly lower than in the other districts. In this district irrigation is not practised. On the other hand, District F has a low winter temperature and precipitation, but plenty of bright sunshine. It has the highest summer temperature of all the districts compared, the lowest precipitation, and abundant bright sunshine. Here irrigation is practised. It is definitely a Dry Belt area. Districts C, D, and E are also Dry Belt regions where irrigation is practised. District B is situated in a transition region between the wet and dry belts. Irrigation is not usually practised, although it is conceded that it would be beneficial.

RESULTS

The Effect of Variety on Food Value of Tomatoes

Examination of the different varieties of tomatoes grown in the University plots showed that in a consideration of appearance and structure of the fruit, Rutgers, Bestal, Harkness and Early Baltimore led in such desirable qualities as medium in size, medium to thin walls, and medium juiciness. However, when their chemical constitution was considered, these same varieties did not show corresponding merit. Harkness and Early Baltimore were relatively low in sugars, while Rutgers and Bestal were low in ash. Valiant was high in vitamin C but low in ash. Earlianna on the other hand, was relatively low in vitamin C in this locality but high

in ash constituents. Little variation was found in acidity (pH) except in the Jan Rue, which is appreciably less acid than the other varieties. Table 2 shows the chemical analyses of the different varieties grown under the same conditions.

TABLE 2.—ANALYSES OF VARIETIES OF TOMATOES GROWN IN THE UNIVERSITY OF BRITISH COLUMBIA EXPERIMENTAL PLOTS

Variety	pH of juice	Dry weight	Ash, fresh weight	Total sugar	Vitamin C*
		%	%	%	
Rutgers	4.05	6.76	0.785	3.98	6.340
Bestal	4.10	6.53	0.689	3.26	5.208
4037100	4.15	6.48	1.232	3.37	5.312
Jan Rue	4.50	6.03	1.214	3.31	5.302
Valiant	4.05	6.25	0.676	3.47	10.416
Harkness	4.10	6.15	1.118	2.75	3.340
Early Baltimore	4.10	6.34	1.048	2.95	4.234
Bonny Best	4.12	5.01	0.949	3.42	5.208
Bonton	4.20	6.41	0.662	3.49	5.290
Earlianna	4.22	6.06	1.285	2.83	6.34

* Vitamin C is expressed as milligrams of ascorbic acid per 100 gms. of fresh fruit.

Table 1 clearly indicates that there is a variation of food constituents in varieties where all are grown in the same area under similar conditions. As will be shown later, no variety is high in total sugars or vitamin C in this locality.

The Effect of Climate and Locality on Food Values of Tomatoes

As previously stated, the 6 districts, A to F inclusive, are all considered as being favourable for the commercial production of tomatoes. Table 1 gave an index as to climatic conditions which exist in these localities. Table 3 shows the chemical analyses of the fruit from the same variety (Earlianna) when grown in these different localities.

TABLE 3.—THE EFFECT OF CLIMATE AND LOCALITY ON THE COMPOSITION OF TOMATOES

Locality	pH	Dry weight	Ash	Nitrogen	Phosphorus	Potash	Total sugars	Vitamin C*
		%	%	%	%	%	%	
A	4.50	6.025	1.296	0.018	0.028	0.131	2.79	8.05
B	4.20	6.809	1.392	0.023	0.032	0.424	3.04	14.58
C	4.25	6.632	1.467	0.007	0.027	0.510	3.90	23.96
D	4.50	6.546	1.085	0.013	0.025	0.974	4.20	31.25
E	4.35	7.561	0.831	0.012	0.023	0.995	4.83	34.25
F	4.22	7.628	1.1254	0.008	0.060	0.850	5.05	38.54
G†	4.30	7.416	1.236	0.016	0.046	0.238	4.00	19.79

* Vitamin C is expressed as milligrams of ascorbic acid per 100 gms. of fruit.
† Ontario sample.

The pH, dry weight, total ash, nitrogen and phosphorus content do not appear to be directly correlated with climate. On the other hand, total

sugars and vitamin C do appear to be correlated. The potash content is higher in the warmer areas, and some slight correlation is indicated between high potash, high sugar and vitamin C content.

The outstanding feature of Table 3 is that the dry areas with the higher temperatures and greater number of hours of sunlight for the growing season produce tomatoes of the higher sugar content and greater vitamin C content. This correlation of temperature and sunlight, sugar content and vitamin C is noteworthy. It is clearly shown in Table 4.

Table 4.—The relationship of temperature and hours of bright sunshine to sugar content and Vitamin C content of tomatoes

Locality	Hours of bright sunshine April to September	Mean temperature April to September	Total sugars	Vitamin C, mgms. per 100 grams
			%	
A	230	59.0	2.79	8.05
B	231	59.5	3.04	14.58
C	239	59.8	3.90	23.96
D	238	62.0	4.20	31.25
E	249	63.5	4.83	34.25
F	254	64.5	5.05	38.54

CONCLUSIONS

The fact that there is a considerable variation in varieties of tomatoes has been clearly demonstrated. But that one variety is better than another for all-round nutritional purposes is difficult to substantiate. If we are particularly interested in any one specific thing, like vitamin C, then we can definitely recommend certain varieties for any one locality, but on the other hand it has been seen that while one variety is higher in one thing than another variety, it is likely to be lower in something else. Is it desirable to grow tomatoes with a high vitamin C content but low ash? If so, would a low-yielding variety be worth growing from the grower's point of view, even if it was from the standpoint of public health?

For the present at least, a tomato with good average quality and desirable characteristics such as colour, shape, handling qualities, etc., together with large yield, is the ideal as far as the grower is concerned. That there is this decided variation in food values in varieties is noteworthy, however, and is worthy of greater consideration by the grower.

In regard to the effect of climate, the results are of especial interest. The warmer districts with plenty of sunshine yield the tomatoes with the greatest vitamin C content. Furthermore, this vitamin C for any given variety is correlated with sugar content.

Besides there being a varietal difference in tomatoes as far as food values are concerned, the locality in which they are grown has a marked effect on their food value. This fact should be taken into consideration in any future planning of agricultural areas.

ACKNOWLEDGMENTS

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A NOTE ON SWEET CLOVER TAINT IN WHEAT[1]

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Sweet clover or melilot taint in wheat has been noted periodically during the past 7 or 8 years by the Canadian grain trade and by overseas importers, who regularly buy Canadian wheat. The matter became acute in 1936. In consequence the Dominion Grain Research Laboratory, Winnipeg, made some investigations into the persistence of the taint in flour and milled products. The results of these tests were positive. In response to these findings the Board of Grain Commissioners caused all wheat in which the taint could be readily detected to be graded "rejected to the grade to which it would otherwise belong". Although the number of cars so graded has never been large, the 1939 crop showed a rather sharp increase, and it was deemed necessary by those close to the situation to do something to prevent the matter from assuming serious proportions. A committee was set up and asked to formulate suggestions to growers as to how to prevent their crops from becoming tainted. That committee, however, was confronted with the fact that there was no authentic evidence available as to the immediate source of the taint. Certain preliminary experiments were conducted, the principal contribution having been made by the Brandon Experimental Farm, and on the basis of these and on "a priori" grounds recommendations as to sweet clover management were offered and published in Circular No. 139 of the Manitoba Department of Agriculture in September, 1939, under the authorship of T. J. Harrison, Assistant Commissioner of the Board of Grain Commissioners.

There is evident need for authentic data on the cause of sweet clover taint. In other words it is important to determine what type of management or handling of the sweet clover crop in relation to the wheat crop causes the latter to take up the objectionable taint. The following limited data are offered as a minor contribution. They are by no means conclusive, but seem to carry some interesting indications.

In the experiment reported, synthetic sheaves of wheat of normal binder size were prepared in which were placed sweet clover plants aggregating about a 4-inch sheaf. Sweet clover in two stages of growth was used. The details appear in Table 1. The threshed samples were immediately placed in air tight containers and were submitted to the grain inspection department of the Board of Grain Commissioners for their designation as to taint. The samples were submitted with key numbers so that the inspectors had no information as to the treatment that had been applied. Following the inspection the samples were taken to the Grain Research Laboratory where a quantitative test for coumarin content was made by Dr. J. A. Anderson in charge of that laboratory. This test is a colorimetric one developed by the Grain Research Laboratory. The data for the colorimetric test are shown in the right hand column of the table and those for the odour test by the grain inspection department in the middle column.

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TABLE 1.—MELILOT TAINT IN WHEAT

Treatment	Odour in threshed sample	Coumarin content in gamma per pound
1. Check, wheat without sweet clover	No odour	0
2. Young sweet clover in butt of sheaf. Threshed immediately.	Strong odour	2000–2500
3. Check, wheat without sweet clover	No odour	0
4. Young sweet clover in the head of sheaf. Threshed immediately.	Strong odour	Less than 1000
5. Young sweet clover in butt of sheaf. Stooked 4 days before threshing.	No odour	0
6. Check. Wheat without sweet clover.	No odour	0
7. Fairly well matured sweet clover throughout sheaf. Stooked 4 days before threshing.	Very slight	Less than 1000
8. Check	None	Less than 200
9. Young sweet clover in head of sheaf. Stooked 4 days before threshing.	Slight	More than 1000

The threshing was done in the order shown in the table. Alternating checks were used in order to pick up taints that might otherwise have accumulated and therefore tainted successive samples or at least those threshed later in the series. This procedure seemed especially important since the threshing was done with a small machine which, on account of the limited surface exposed to such juices as might be expressed in the threshing process, would "dilute" or disperse those juices less than a large machine. The fact that the checks showed no taint naturally increases confidence in the technique and therefore in the results.

According to the tests by the grain inspection department, a strong odour was shown by each of the sheaves containing young sweet clover which were threshed immediately after they were prepared so that there was no opportunity for the sweet clover to dry. This was fully supported by the coumarin test in the case of sample 2. In the case of sample 4 the coumarin test indicated a medium odour. All of those sheaves containing sweet clover that were threshed 4 days after they were prepared, and therefore after they had dried considerably, showed less odour than those that were threshed immediately (Samples 5, 7, and 9). Sample 5, containing young sweet clover in the butt of the sheaf showed no odour according to either test. Samples 7 and 9 showed "very slight" and "slight odours" respectively and coumarin contents indicated as "less than 1000 and more than 1000" suggesting respectively medium and strong odours. Sample 2 was prepared to simulate straight combining of wheat with which sweet clover had been sown in the spring. Sample 4 would represent straight combining of wheat containing volunteer 2-year-old sweet clover plants. Sample 5 would represent binder harvested wheat with which sweet clover had been sown in the spring. Samples 7 and 9 were intended to simulate binder harvested wheat containing volunteer 2-year-old plants, in relatively early and well advanced stages respectively.

CONCLUSIONS

While these limited data establish nothing they suggest that the hazard of taint is greatest where green sweet clover is present in the crop when threshed. A scattered growth of volunteer sweet clover in the crop may not produce tainted wheat if the material is well dried in the stook before threshing. The same is probably true of young growth resulting from sowing sweet clover with the wheat in the spring. Straight combining would seem to involve the greatest hazard.

COMPATIBILITY OF BECHTEL'S CRAB ON SOME MALLING ROOTSTOCKS[1]

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Dwarfing rootstocks have been suggested as a means of reducing the size of flowering crab trees and thereby making possible their use where a large tree would be objectionable. One of the finest of these ornamentals is Bechtel's Crab (*Malus ioensis* Brit. var. plena Rehd). On a compatible standard rootstock it may attain a height of 15 feet and a spread of 20 feet, a tree of such size that it would be unsuitable for many locations.

Jaune de Metz (Malling IX), the most dwarfing of all the Malling apple rootstocks, comes to mind as being of special value in producing a tree of considerably smaller size. Unfortunately Bechtel's Crab appears to be wholly incompatible on this rootstock. Budding of 11 plants in 1938 and 20 plants in 1939 failed to give a single tree. The Massachusetts Station reports a similar result (3). Close observation in 1940 showed that there had been a union between bud shield and rootstock but when other apple buds commenced to burst into leaf, the still dormant Bechtel's buds began to drop out of the shield, the last one disappearing about mid-June. In the latter part of May the bud shields themselves began to disintegrate and, by mid-June, had almost completely disappeared. Neither Argyles (1) nor Chang (2) deal with similar manifestations of incompatibility though it is reasonable to suppose that this may not be an uncommon one.

Table 1.—Bechtel's Crab budded on several Malling Rootstocks, 1938

Rootstock	Number budded Aug., 1938	Number growing May, 1939	Number broken at union July-Aug. 1939	Colour of leaves, Oct. 19, 1939	Approx. foliage remaining on tree, Oct. 19, 1939
					%
Malling I	7	6	0	Green	75
II	16	16	0	Red	20
IX	11	0			
XII	4	1	0	Green*	
XIII	11	8	7	Red	50
XV	3	2	2		
XVI	24	18	1	Red	50

* Only a shoot 1 inch long which died the following winter.

Other Malling rootstocks show varying degrees of incompatibility with Bechtel's Crab (Table I). Chang (2) gives early autumn coloration of foliage and early leaf fall as two symptoms of incompatibility. By these

[1] Contribution from the Horticultural Experiment Station, Ontario Department of Agriculture, Vineland Station, Ontario.
[2] Chief in Horticultural Research.

standards Malling I, among the above list of rootstocks, appears to give the most promise of compatibility with Bechtel's Crab. It is worthy of note also that the trees on this rootstock, tops now 2 years old, are the largest of all. Evidences of incompatibility appear with Malling II, XIII, and XVI in poor take of buds, breakage of budlings at the union or in early coloration and dropping of the leaves. With regard to Malling XII and XV the numbers are too few to permit any conclusions being drawn. The budding of Bechtel's Crab on Malling XIII and XV the following year (1939) resulted in better takes and less breakage of budlings but showed the same early autumn leaf coloration and fall as the first lot. A few Bechtel's Crab trees on Malling XVI from 1932 budding are growing on the Station grounds. They have been very weakly vegetative and in 1940 were still very dwarf trees. Our results with Bechtel's Crab on Malling XII, XIII and XVI are not in agreement with those reported from Massachusetts (3) where this variety is said to be doing well in the nursery when budded on these rootstocks.

In 1938 *Malus aldenhamensis* and an open pollinated seedling of *Malus pumila* var. Niedzwetzkyana, both ornamentals, were budded on the same lots of Malling rootstocks used for Bechtel's Crab and in the same quantities. With these kinds there were no evidences of incompatibility in the nursery row.

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INVESTIGATIONS OF BREEDING TECHNIQUE FOR THE SUNFLOWER (*HELIANTHUS ANNUUS* L.)[1]

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INTRODUCTION

A review of literature on *H. annuus* L. reveals that there is little available information relating to breeding methods for this crop. Consequently, in conjunction with the general breeding program, studies have been conducted with a view to the development of satisfactory crossing and inbreeding techniques. The object of this paper is to describe the breeding procedure which has been found to be most satisfactory and to discuss some of the effects of inbreeding in this species. The methods described are based upon fundamental studies relating to flowering processes in sunflowers as reported by Putt (8).

LITERATURE REVIEW

A crossing technique, which is practised at the Saratov Plant Breeding Station is described by Arnoldova (1). The ray flowers and corollas, anthers and stigmas of the disc flowers opening on the first day of flowering are removed from their ovaries before the stigmas emerge. The flowers opening on the following day are emasculated by grasping the "tops of the stamen filaments" when the anthers are fully developed. The bulk of adhering pollen is blown off and odd grains are removed with a brush. After emasculation the corolla and enclosed organs of those flowers which have not been treated are pulled out with forceps, leaving the ovary in the head. Pollination is done when the stigma lobes have opened out after emasculation and the head is then isolated with a cotton sack. Because of the rough, sticky surface of sunflower pollen, penetration of pollen from other plants through the cotton sack is not considered likely.

Wagner (9) described four different emasculation procedures and presented data as to their relative efficiency. He concluded that removal of the anther tube after the pollen dehisces, and washing off the pollen adhering to the stigma with a fine spray was the most suitable procedure.

Cockerell (2) reported obtaining crosses in one case by merely growing the two annual species together without any attempt to control crossing. In other crosses Cockerell apparently emasculated and pollinated, but he did not describe his methods. Hamilton (5) referred to crossing inbred lines, but did not describe the technique employed.

Platchek (7) found a range in self fertility from completely sterile to highly fertile types. Wagner (9) stated that *H. annuus* could be isolated into self-sterile and self-fertile lines. He noted that the self-fertility relationships of *H. cucumerifolius* were similar to those of *H. annuus*, while the perennial species were completely self-sterile. McRostie (6) found some self-fertility but Cardon (3) observed a high degree of self-sterility in plants of the Mammoth Russian variety.

[1] Contribution from the Dominion Forage Crops Laboratory, Saskatoon, Saskatchewan, being a summary of a portion of a thesis submitted to the Graduate School of the University of Saskatchewan in partial fulfilment of the requirements for the degree of Master of Science.
[2] Agricultural Assistant.

In selfing by bagging Wagner (9) secured a decided increase in seed setting by brushing the pollen over the stigmatic surfaces. The type of bag used was not specified. Both Wagner (9) and Platchek (7) referred to the reduction in fertility under isolation. In selfing, McRostie (6) found it necessary to use as isolators, material which would exclude wind borne pollen. Cotton bags were found unsatisfactory. Hamilton (5) used heavy manilla paper bags as isolators and secured a seed set of 15 to 30%.

Platchek (7) observed that inbreeding brought out many undesirable recessive characters, but that it enabled the breeder to isolate lines with valuable agronomic characters such as earliness and immunity to certain diseases and insect pests. Hamilton (5) noted a marked increase in uniformity after three generations of inbreeding, but a definite reduction in plant size in many strains.

Pollen longevity was studied by Arnoldova (1). He found that pollen stored in paper packets under ordinary room temperatures when used on emasculated stigmas gave 60 to 80% seed setting after 30 days storage, and 36% seed setting after 11 months storage. Wagner (9), on the other hand, apparently considered the pollen was very short lived.

STUDIES OF CROSSING TECHNIQUE

Emasculation

A preliminary step in emasculation is the removal of the ray flowers and the involucral bracts from the head on the day that flowering begins. The removal of these large accessory organs is advisable in order to make the flowers on the disc more accessible to work with, and to do away with a large surface area on which pollen could lodge. The ray flowers are easily pulled off and the bracts can be cut away with a small pair of scissors.

From observations on flowering it was found that an occasional flower opens and is fertilized before the ray flowers are completely open. For this reason the outermost flowers are removed, for the first two or three days of flowering, in the forenoon of the day that they open, thus preventing fertilization of their ovaries which are left in the head. This procedure assures that at maturity only the seeds which are found about an inch from the edge of the head are the seeds resulting from the controlled cross. Any seeds found at the edge will definitely be selfs or uncontrolled crosses.

Knowing the flowering behaviour of the individual flowers in the head, it is obvious that the best time to emasculate is at the stage when the anther tube is fully extended, and before the stigma has grown up inside it. While the logical time appeared to be prior to the dehiscence of the pollen onto the stigma, the period between the full extension of the anther tube and dehiscence was so short and occurred at such an early hour that emasculation at this stage was not practical. Accordingly, the anther tubes are removed after dehiscence, but before the stigmas have grown up inside them to any great distance. On a warm, clear day this means emasculation must be done by about 10.00 a.m.

The anther tubes are grasped with forceps and gently pulled off over the stigmas. Care is taken not to seize them too low down and pinch the stigmas inside, causing the lobes to separate in the operation. After the

FIGURE 1. Left to right: a freshly emasculated flower; two flowers morning after emasculation; an unfertilized flower 3 or 4 days after emasculation.

anther tubes are removed excess pollen adhering to the stigmas is blown off. Any stigmas whose lobes separate during the work are discarded. The head is then isolated with a paper bag.

On the following morning the stigma lobes are separated, exposing the receptive surfaces. In Figure 1 a freshly emasculated stigma is shown at the left. The centre two are ready for pollination on the morning after emasculation. It should be noted that this method of emasculation does not entirely free the stigmas of their own pollen, but it does remove all that is loose and liable to come in contact with the receptive surfaces of the stigma when they become exposed.

It is easily seen that if unopened and untreated flowers of the head were allowed to remain, early the following morning these would be shedding pollen and effecting self-pollination of the emasculated flowers. In the first two seasons of work these were removed at the same time that emasculation was performed by pulling each one away from its ovary individually with tweezers. This was a tedious, time consuming task.

In 1939 a knife, suited to cutting these central florets away, was constructed. A pair of cover slip tweezers was split and each portion mounted in a small wooden handle, then one side of the tip sharpened, providing a knife with a small blade set at an angle to the handle. Following this development the practice has been to cut away the bulk of the central flowers, which are not required, on the day before emasculation. It is not possible to cut every unnecessary flower away because there is no clearly defined line of demarkation between the flowers opening on different days.

Most of them, however, can be removed and the few remaining can be pulled out individually with the tweezers at the same time that emasculation is done. Removing the bulk of the central flowers on the day of emasculation is not advisable because the handle of the knife and the fingers inevitably come in contact with the anther tubes of the flowers to be emasculated. Such irritation causes a high percentage of stigmas to divide during emasculation. This statement may seem contradictory to pulling out the few individual flowers at the same time as emasculating, but in working with tweezers they are always vertical to the plane of the head, and do not come in contact with the flowers to be emasculated nearly as much as the knife handle does.

Figure 2 illustrates a head in the process of emasculation. In the area around the edge of the head the flowers have been pulled off soon

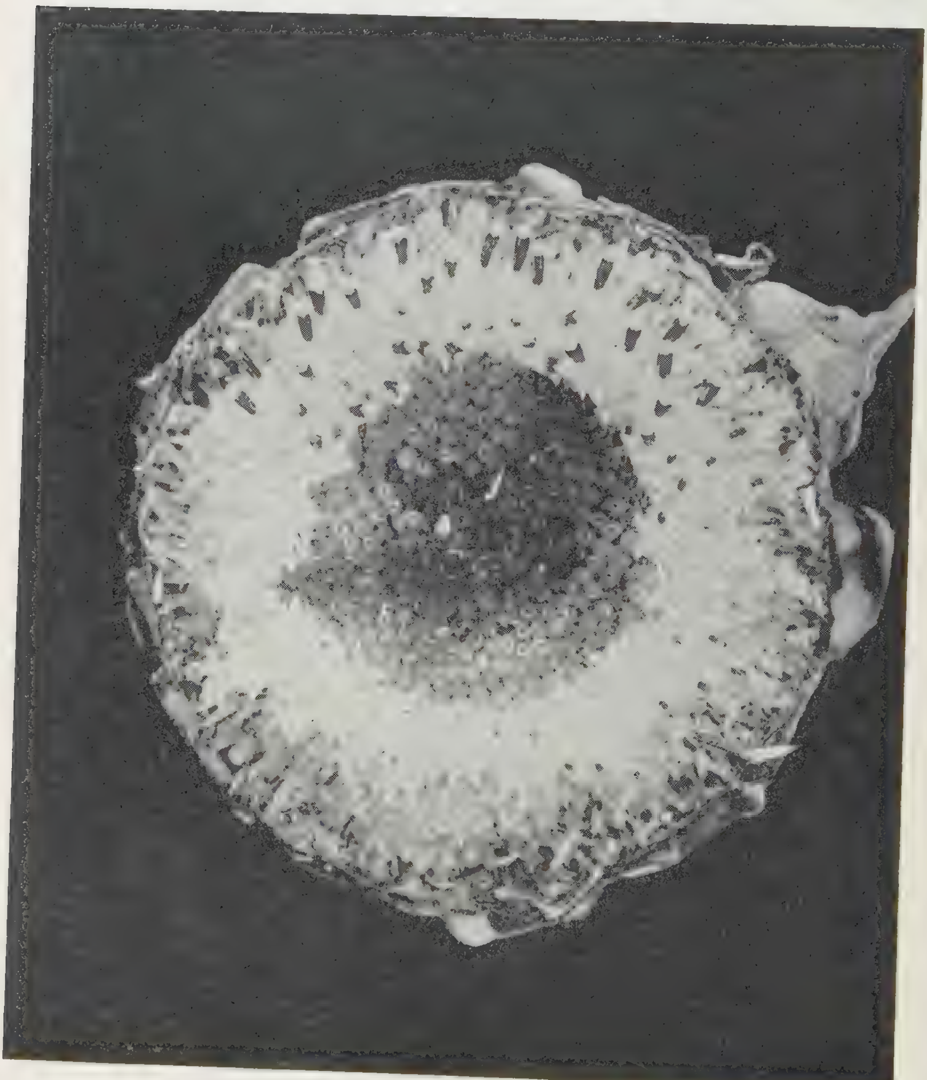

FIGURE 2. Head in process of emasculation, upper flowers entire, lower flowers emasculated.

after they opened. In the central section the flowers were cut away on the day preceding that on which emasculation was done. The ring of flowers left for treatment is also shown. The photograph was taken on the morning the emasculation was being performed. The untreated flowers can be seen on the upper portion of the head with their anther tubes extended ready for removal, while in the lower portion the freshly emasculated stigmas can be seen.

Pollination

The pollen is collected by placing a bag over the head of the male parent a day or two before flowering begins. The bagging of the male parent prior to commencement of flowering is advisable in order to avoid contamination by foreign pollen lodging in the head. On a normal plant a day or two after flowering commences adequate amounts of pollen will be found in the bag. It is suitably applied by means of a brush made from a small piece of cotton batting rolled on the end of a toothpick. This is dipped into the pollen and then gently drawn across the receptive surfaces of the stigmas. The brush is then discarded, a new one being used for each cross. A camel's hair brush was tried in a few cases but did not appear satisfactory. The pollen did not adhere well to it and furthermore it is necessary to disinfect the brush between each operation to avoid contamination. Pollen adheres well to the cotton batting brush. Contamination is not likely when a new one is made for each cross, care being taken to wipe the hands before making the brush and to keep the batting in a pollen-tight container. A small can such as is commonly used for collecting insect specimens has been found quite satisfactory.

The morning following pollination the stigmas of those flowers which have been fertilized have withered and receded. Others will remain in a fresh condition and begin to show an elongation and coiling of the lobes, as illustrated at the extreme right in Figure 1. Repollination, however, is seldom necessary.

Duration of Stigma Viability

To determine the length of time that emasculated stigmas will remain viable, a test was conducted over a 3-year period. In each year a number of plants of Mennonite origin were emasculated on the same day, and on each of succeeding days two of these plants were pollinated with freshly collected pollen. Later the percentage seed setting was determined to give an indication of the loss in viability of the stigma with age.

The results of this study showed a progressive decrease in seed setting with increasing age of the stigma. The average percentage seed setting for stigmas 1, 4, 5, and 9 days old was 74.4, 63.0, 43.3, and 9.6% respectively. Thus it is evident that pollination in controlled crossing should be completed within 5 days after emasculation. Observations on the behaviour of the stigmas also support this conclusion. For the first 2 or 3 days following emasculation they show a coiling of the lobes, but after 5 or 6 days they are generally withered. For this reason it is felt that any seed secured from pollination after 5 days of age is largely self-fertilized seed.

Duration of Pollen Viability

In the present study a number of tests have been conducted to determine the longevity of sunflower pollen. In 1937 pollen from a single plant stored in a cork-stoppered vial showed no decrease in seed setting secured over a period of 6 consecutive days, when applied to emasculated stigmas. With fresh pollen the percentage of seed set was 86%, and with pollen 6 days old, 84%.

As Arnoldova (1) claims sunflower pollen stored for a period of 11 months gave fair seed setting, composite pollen collected on August 17, 1937, was stored for use on emasculated flowers the following summer. Cork-stoppered vials containing the pollen were stored in an ice refrigerator and in the laboratory under normal room temperatures. The contents of these vials were used to pollinate emasculated flowers on July 15, 1938. No seed setting was secured from the vial stored in the laboratory, while that from the refrigerator gave a seed setting of only 3%. It is quite likely that the seeds in this case were due to selfing rather than fertilization from the pollen applied.

In 1939 a composite sample of pollen was collected on August 12 and stored at room temperatures in a vial with a cotton batting stopper. This pollen was used on emasculated flowers after various periods of time had elapsed. The results of this test are shown in Table I.

Table 1.—Seed setting following pollination with pollen stored for various lengths of time at room temperature

Female parent	Age of pollen (days)	No. of flowers treated	No. of seeds	Per cent of seed setting	Average of two plants
S-797	2	73	50	68.5	
S-797	2	93	56	60.2	64.4
S-797	5	150	73	48.7	
S-796	5	155	99	63.9	56.3
S-799	8	185	21	11.4	
S-799	8	215	7	3.3	7.4
S-797	11	105	10	9.5	
S-802	11	94	37	41.5	25.5
S-802	15	225	86	38.2	
S-805	15	187	161	86.1	62.2
S-802	21	151	14	9.3	
S-801	21	185	12	6.5	7.9
S-806	25	103	52	50.5	
S-801	25	100	0	0.0	25.2

From Table 1, it is seen that the seed setting fluctuated widely between treatments and also within treatments. The necessity of using different plants as females for each treatment undoubtedly introduced a serious source of variation (cf. S-797 with S-802, and S-806 with S-801). The rise to 62% seed setting obtained with 15-day-old pollen following a low of

7.4% seed setting with 8-day-old pollen is inexplicable. When plants of the strains of the 15-day treatment were isolated, using heavy paper bags, 5 plants of S-802 set only 84 seeds, or an average of 17 seeds per plant, while 6 plants of S-805 set only 23 seeds or an average of 4 seeds per plant. This is strong evidence that the seed setting obtained in the 15-day treatment was not the result of self-fertilization. The 15-day-old pollen was evidently as viable as the 2-day-old pollen.

It seems reasonable to conclude from these studies that pollen can be stored without serious loss of viability for at least one and possibly two weeks at ordinary room temperature. Storage from one season to another, however, does not appear feasible.

Suitability of Crossing Technique

Following the description of the emasculation and pollination techniques, it is logical to ask how successful they are for securing crosses. In the first year of work an attempt was made to check this by pollinating part of the emasculated flowers on a head and leaving the remainder of the flowers as checks. Because of the difficulty of controlling pollen the method was not very reliable as a check on emasculation. The results were not valueless, however. On 5 plants, 379 flowers emasculated and not pollinated showed a seed setting of 46.7%, while 467 flowers emasculated and pollinated showed a seed setting of 85.2%, indicating that the foreign pollen being applied was increasing seed setting.

Because of the large amount of seed secured on checks, this method was not used in succeeding years to any extent. Neither has any extensive effort been made to check emasculation effectiveness by isolation of treated flowers, because of the high degree of self-sterility which often exists. In 1938, 62 emasculated flowers on a plant of a highly self-fertile line were isolated and they set 7 seeds, or 11.3%, which would indicate that emasculation was fairly successful.

The proportion of crosses to selfs provides the critical test of the success of a crossing technique. In 1937 and 1938 crosses were attempted between plants differing in respect to one and usually two clearly defined contrasting characters, so that the crosses could be readily distinguished from the selfs in the F_1. Table 2 presents a summary of the crossing success.

As shown by this table, the crossing success ranged between 83 and 100%, and averaged 92.3%. It is also worthy of mention that the female parents, in all except Cross 18, showed a considerably higher than average degree of self-fertility. These facts speak well for the efficiency of the crossing technique.

An interesting fact was brought out in the progeny of Cross 7. The female parent, which was a highly self-fertile line, was emasculated rather late in the day and the stigma lobes of every flower separated in the operation. The foreign pollen was applied in the normal way the following morning, and a seed setting of 75% was secured on 145 flowers. A progeny of 34 plants grown the following year showed 88% crosses.

It is very likely that in the emasculation of this plant it became self-pollinated. Yet when foreign pollen was applied 24 hours later 88% crosses were secured. The result suggests that foreign pollen is able to

germinate and effect fertilization on a given plant much more rapidly than its own pollen. This idea is further supported by the fact that heads isolated with paper bags always show coiling of the stigma lobes, as shown at the right in Figure 1. This elongation and coiling seems to occur no matter how highly self-fertile the plant may be, indicating that the plant's own pollen is slow in effecting fertilization.

Table 2.—Crossing success in various attempted crosses

Cross number	Progeny—Number of		Per cent crosses
	Crosses	Selfs	
—	30	6	83
8	24	0	100
9	23	1	96
18	26	0	100
7	30	4	88
Total and average	133	11	92.3

If this assumption is correct, it should be possible to produce controlled crosses in large numbers, simply by isolating the heads and applying foreign pollen to the flowers without troubling to emasculate them. Even if controlled crosses were not wanted in large numbers, the time saving in crossing, even to a small extent, without emasculation would be substantial. Consequently the method appears to warrant a trial in future years.

STUDIES OF INBREEDING METHODS

Large size paper bags have been used for isolating in the main breeding program. In 1937 a 10-pound pag was used, while in 1938 and 1939 a 20-pound size was necessitated by the larger size of head resulting from better weather conditions. Even this large size was not sufficient, in some cases, large heads, as they developed, occasionally splitting the bags. However, no evidence of crossing due to splitting of this nature has been found. The stigmas were usually past the receptive stages when the break in the bag occurred. While the bags used could have been larger in diameter, they were longer than necessary. Each year about five inches of needless length was cut off the end in order to reduce the wind resistance of the bagged head and thus minimize the danger of stems bending over or breaking in high winds.

In 1937 the glue of the bags used was often moistened with slight rains, permitting the seams to open. In a few cases bees were found inside these bags so that some crossing may have occurred. In the succeeding years a bag with better glue was used and no splitting was observed. Another precautionary measure adopted has been to place the bags on the head with the seam on the east side. As the head develops it bends over in an easterly direction and brings the seam to the lower side, so that it is not wet easily by slight showers.

Studies have been conducted over the 3-year period to determine the value of manipulation for increasing the seed setting under paper bags. In the first year one-half of the head on 19 plants was manipulated by

FIGURE 3. Double stemmed type plant used in study of value of manipulation with paper bags as isolators.

drawing a cotton batting brush, similar to that used in crossing work, over the surface of the stigmas every second day. The average seed setting percentage was 20.07 for the manipulated portion, and 14.27 for the check, a difference of 5.8% in favour of the manipulation. It was quite evident that in removing the bag for manipulation a great deal of pollen was spread over the stigmas of the portion of the head not manipulated. Thus the portion not manipulated could not be considered a reliable check, as it would not be comparable to leaving the paper bag on the head undisturbed for the full period of flowering.

To overcome this objection the study in 1938 and 1939 was conducted on plants of the type that is illustrated in Figure 3. These are plants which have received an injury to the terminal growing point, and as a result send up a few large branches, often only two, which are almost identical. A few such plants were observed in 1937 occurring naturally. In the succeeding two years a larger number were produced artificially

Table 3.—The effect of manipulation upon seed setting of heads selfed with heavy paper bags

	1938		1939		Mean of 2 years
	No. of plants	Mean percentage seed setting	No. of plants	Mean percentage seed setting	
		%		%	%
Manipulated	25	22.64	20	35.90	29.27
Not manipulated	25	7.84	20	20.92	14.38
Difference		14.80		14.98	14.89
t value		4.45		4.99	
Probability		.01		.01	

by cutting out the growing point of the plant at an early stage. This type of plant provided a perfect means for checking the value of manipulation. Both heads were bagged at the same time. One was left undisturbed, and the other one was manipulated every second day with a cotton batting brush. A summary of the data secured in 1938 and 1939 from work on this type of plant is given in Table 3.

The results show that as an average of the two years the seed setting was increased by 100% through manipulation. A t value, calculated on the basis of paired variables (4), gives a probability of much less than 0.01, showing that the difference is significant by odds of greater than 99:1 in both years.

Two factors justify the conclusion that this increase is due to manipulation and an increase in self-fertilization rather than contamination from foreign pollen: (1) great care was taken to avoid contamination; (2) in both years one plant which appeared normal in other respects did not set seed under either bag. If contamination from outside pollen had occurred seed would have been expected in the heads which had been manipulated.

Besides the work with paper bags, some heads have been isolated with cloth bags, and some with tiffany bags, as reported by Putt (8). Part of the heads under cotton bags were manipulated each year by rubbing the hand over the surface of the head without removing the bag. The following average percentages seed setting were secured over the 3-year period on comparable material:

	%
Cotton bags (manipulated)	37.60
Cotton bags (not manipulated)	14.02
Tiffany bags	26.88
Paper bags	10.92
Open fertilized check	66.12

It is felt the high figure for the manipulated cotton bags is due to a large amount of crossing from foreign pollen lodged on the bag being rubbed through it during manipulation. This figure is over $2\frac{1}{2}$ times as great as that for cotton bags not manipulated, and even 11% higher than the open

mesh tiffany bags. Thus it hardly seems probable that this high seed setting is due to an increase of self-fertilization in comparison with the other methods. The slightly higher percentage shown by the cotton bags which were not manipulated in comparison with the paper bags may be due to a freer circulation of air and better light conditions which they permit. However, as the paper bags do give fair results when used as isolators, it is felt their use should be continued until a check can be made by growing progenies from the different methods of isolation. The progeny check up would determine the amount of crossing which is occurring with each method.

EFFECTS OF INBREEDING

Uniformity

In 1937 five or more plants of each of the lines were isolated with paper bags. Progenies from the resulting selfed seed of a number of the most desirable selections were grown in 1938, and the process repeated. In 1939 a number of second generation selfed progenies were grown.

The trend to increased uniformity has been quite noticeable in the Mennonite material which was very heterogeneous in the first year. In 1937 most of the lines showed a large variation in the degree of branching. In 1938, lines pure breeding for the vigorous branching character were secured, and in 1939 several lines approaching purity for a single stem were showing in the field nursery. In general, there was also a noticeable increase in uniformity of height, stem strength, maturity, length of internode, length of petiole and leaf shape exhibited in the 1939 nursery within the lines, as compared to the original material grown in 1937.

The most noticeable and clearly defined increase in homogeneity has been in seed colour. A classification of the condition for seed colour in the Mennonite lines is given in Table 4. which shows the definite trend of increasing uniformity in this material.

Table 4.—Data showing increased uniformity in seed colour of Mennonite lines following inbreeding

	No. of uniform lines	No. of lines not uniform	Total no. of lines	Percentage lines uniform
1937	19	188	207	9.2
1938	36	147	183	24.5
1939	53	47	100	53.0

Self-fertility

In order to secure data on seed setting when isolated, the bagged heads were threshed separately, the seed from each cleaned and the percentage seed setting estimated for each plant. A frequency distribution showing the number of plants in various percentage groups is shown in Table 5. It should be pointed out that the Mennonite material was first selfed in 1937, but that prior to its receipt at the Dominion Forage Crops Laboratory the selfing history of other material is unknown.

Table 5.—Summary of seed setting on plants isolated under paper bags

	Total no. of plants	Percentage distribution in fertility classes						Percentage plants setting seed
		0.0	Under 10%	10–25 %	25–40 %	40–50 %	Over 50%	
Mennonite Lines								
1937	1,036	10.4	50.8	13.5	10.2	8.6	6.5	89.6
1938	1,046	11.8	63.4	7.6	6.2	5.0	6.1	88.2
1939	629	18.4	51.8	16.7	4.8	6.4	1.9	81.5
Total and average	2,711	12.8	55.9	12.0	7.4	6.7	5.3	87.2
Ottawa Inbred Lines								
1937	54	0.0	3.7	13.0	5.6	9.3	68.5	100
1938	145	0.0	10.3	15.2	31.7	26.9	15.9	100
1939	30	0.0	16.7	23.3	6.7	30.0	23.3	100
Total and average	229	0.0	9.6	15.7	22.3	23.1	29.3	100
Russian Lines								
1937	50	0.0	32.0	14.0	18.0	8.0	28.0	100
1938	47	0.0	36.2	10.6	17.0	12.8	23.4	100
1939	53	5.7	20.8	20.8	13.2	20.8	18.9	94.3
Total and average	150	2.0	29.3	15.3	16.0	14.0	23.3	98
Ottawa Lines (European Origin)								
1939	74	37.8	55.4	4.0	2.7	0.0	0.0	62.2

The outstanding feature shown by the data of Table 5 is a decrease in self-fertility following each of the two generations of selfing in the Mennonite lines. Calculating a Chi-square for the 1937 and 1938 results, and for the 1938 and 1939 results in each case using the actual number of plants and considering them as a $2 \times n$ fold table, gives values of 53.6 and 69.2 respectively, both of which correspond to probability values of much less than 0.01. As the data were recorded by different workers in the three years, there could be some personal bias in the estimation of seed setting percentage which might account for such a large Chi-square value. To eliminate any such bias the data were reconsidered on the basis of a 2×2 fold table, classifying the material as self-fertile (i.e., setting some seed) and non-self-fertile. The Chi-squares calculated from this classification for the results of 1937 and 1938, and 1938 and 1939 give values of 0.939 and 14.34 respectively, corresponding to probability values of 0.30–0.50 and less than 0.01. Hence, while these results cannot be considered entirely conclusive, there is a strong indication of a highly

significant decrease in self-fertility following inbreeding, and especially between the first and second generations of inbreeding. This fact is all the more striking when one considers that plants with more than an average degree of self-fertility were selected to grow the self-line progenies from, any plant which gave less than 25 seeds, and for the most part less than 45 seeds being avoided.

Considering the material from the different sources, there is a noticeable difference in the degree of self-fertility. The Mennonite lines and those of European origin introduced from Ottawa in 1939 show the lowest seed setting, the latter group being notoriously poor seed setters when isolated. The Ottawa inbred lines showed a high degree of self-fertility, in several instances plants setting seed under isolation almost equal to that under open-fertilized conditions. The Russian material occupies a position intermediate between that of the Ottawa and Mennonite lines, very few plants failing to produce seed, but a large group showing a relatively low seed setting under isolation.

Marked differences between lines within the same material were also evident. For example, in 1939 one Mennonite line produced only 75 seeds on 10 isolated plants, 59 of these being on 1 plant, while another line growing adjacent to it produced over 3,200 seeds on 9 isolated plants. Three plants in Russian material which failed to set seed in 1939 were all in one line, and the only two other plants isolated in this line showed less than 10% seed setting, giving another indication of the definite and clear cut degree of fertility in different lines.

It is of value to note that the parent selected for seed in 1939, in the case of the above mentioned Russian line, was somewhat lower in seed setting than the average of the group from which it was chosen, and it became the parent of the first plants which failed to set seed in this material. Such a result suggests that any tendency to self-sterility, as shown by low seed setting under isolation, should be carefully avoided in making selections which are to be carried along under an inbreeding program.

SUMMARY

1. A successful crossing technique which is simple and easily performed is described. Emasculation is performed by removal of the anther tubes early on the morning that the flowers open. Excess pollen is blown off and flowers not wanted are removed from their ovaries before fertilization occurs. Pollination is effected the morning following emasculation.

2. A study on the viability of the stigma indicated that pollination should be effected within 5 days after emasculation.

3. Tests on pollen longevity indicated that pollen could be stored for one week and possibly two weeks without loss of viability. Storage of pollen from one season to another did not appear feasible.

4. Paper bags proved to be fairly satisfactory as isolators in an inbreeding program.

5. Manipulation of flowers isolated with paper bags gave an increase of 15% in seed setting. This increase appeared directly attributable to an increase in the amount of self-fertilization occurring.

6. Following two seasons of inbreeding with material of Mennonite origin, there was a decided increase in the uniformity of morphological characters within lines.

7. A decrease in self-fertility in Mennonite material following two years of inbreeding was demonstrated.

8. Seed setting secured on isolation showed that striking differences existed in the degree of self-fertility between material of different origin and between different lines of the same material.

9. There were indications that selection of plants with a low degree of self-fertility, as parent material for lines to be carried in an inbreeding program, is an undesirable practice.

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THE DISTRIBUTION OF BRACKEN IN ITS POSSIBLE RELATION TO BOVINE HAEMATURIA IN BRITISH COLUMBIA[1]

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Botanical surveys in the fall of 1930, in the spring of 1931, and again in the summer of 1939, were a phase of an investigation by officers of the Dominion Department of Agriculture on a disorder of cattle in British Columbia known as redwater disease *(Haematuria vesicalis)*. This trouble has persisted in the lower coastal region practically from the pioneer clearing of the land (14) and has baffled all efforts to discover a causative agent. As usual following unaccountable loss of animals, various plants, including in this case bracken or brake fern, have come under popular suspicion. The possible responsibility of some has been investigated but with little resulting satisfaction. While feeding experiments carried out by Hadwen and Bruce (10) seemed to implicate bracken in a poisoning of horses called "staggers", all feeding results in connection with redwater disease of cattle were reported as negative. Since no adequate survey of the vegetation had ever been undertaken it was hoped that efforts in this direction might bring to notice some plant itself the cause, or which might provide a clue to the cause, of redwater. The possibility of bracken still being that plant was not overlooked.

With study of notes and collections still incomplete many hundreds of species have come under review in the light of such criteria as range, prevalence, incidence of occurrence on redwater and clean farms, consistency of presence on all redwater farms and known unwholesomeness. Analysis of the data has narrowed consideration to comparatively few species, which are discussed in unpublished Divisional reports (9), and of which bracken appears to be entitled to this additional notice. While no evidence of bracken or other plant poisoning has been adduced there might well be an indicator rôle for this fern.

RANGE

In parts of British Columbia bracken, *Pteridium aquilinum* (L.) Kuhn var. *lanuginosum* (Bong.) Fernald,[3] is one of the most conspicuous among herbaceous plants, growing to extraordinary size and densely invading recently cleared or burned over land, pastures and roadsides. There are other parts of the province in which it is not to be seen. On the accompanying map closed circles mark the locations at which this fern was among the plants recorded, while open circles locate the remaining surveys made on six excursions in as many years west of Meridian 114. Necessarily in a country of such uneven development surveys are not uniformly distributed.

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[3] Since this paper was accepted for publication another, *A Revision of the Genus Pteridium*, by R. M. Tryon, Jr., has appeared (Rhodora 43 : 1-31, 37-67, 1941). There all brackens of the world are regarded as varieties of *Pteridium aquilinum* (L.) Kuhn. The fern of British Columbia would be variety *pubescens* Underw., and that of Eastern Canada variety *latiusculum* (Desv.) Underw.

From the map it would appear that the Rocky Mountains are an eastern barrier for this species. Along the several lines of survey westward through the mountains bracken was never observed until this range was left behind. However, from specimens in the National Herbarium, Ottawa, there is evidence for at least sporadic occurrence on the eastern slope, twice from the neighbourhood of the Hot Springs, Banff, and once from an altitude of "4,200–6,000 feet" in Waterton Lakes Park. Bracken, in plant lists from Rocky Mountain States to the south, is probably also mostly west of its peaks. According to Fernald (8) "*Pteridium aquilinum* var. *lanuginosum* is the common bracken of western North America, from Alaska to California, Arizona, New Mexico and the high mountains of western Texas, south along the mountains to Guatemala, with an eastern extension into the Black Hills of South Dakota. East of the Black Hills it is highly localized", and these eastern occurrences he regards as of the nature of Cordilleran relics. The common bracken of the East is *Pteridium latiusculum* (Desv.) Hieron, and its range is given by Broun (4) as "Newfoundland to Wyoming, south to extra-tropical Florida and Arizona." With only such over-lapping as is thus indicated, the two species are virtually absent over many hundreds of miles of intervening plains.

ECOLOGY

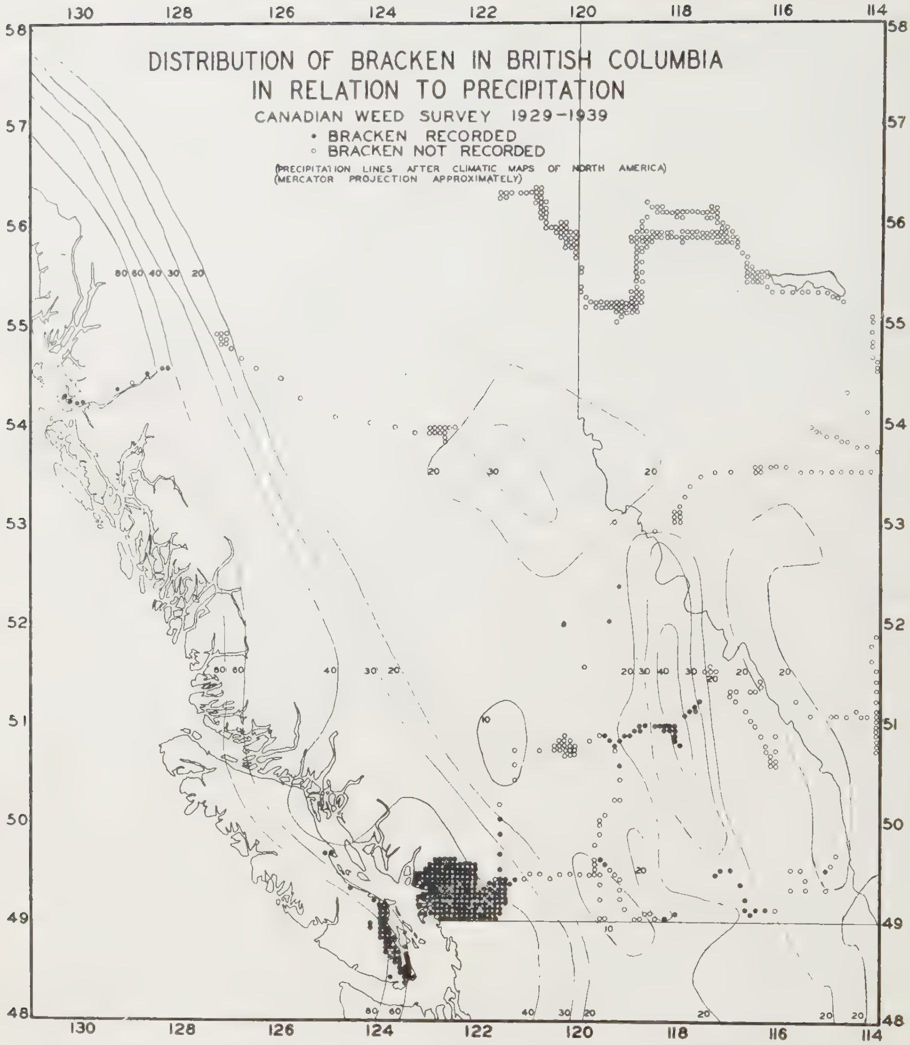
Within British Columbia it is possible to assign most records to one or the other of two belts, one coastal and the other somewhat west of the Continental Divide. The coastal belt, extending north and south beyond the limits being studied, was not found to reach inland beyond the Skeena River district in the north or up the Fraser River much beyond North Bend. There was opportunity for only one brief survey between these points in the coastal region, and while this list, made along the streets of Ocean Falls, failed to include bracken, the fern has been listed at nearby Bella Coola by Harlan I. Smith (16), and it is known from Queen Charlotte and other coastal islands. The inland belt might be said to reach from the southern end of Kootenay Lake through Revelstoke and northwestward to the line of the Canadian National Railway (one specimen seen in the National Herbarium was from Quesnel Lake beyond this), and roughly paralleling the Selkirk and Cariboo ranges. From east to west along the Canadian Pacific Railway the belt has a width of more than two meridians, from Donald on the Columbia River (13) to about Shuswap. A few records scattered outside these two principal areas, i.e. at Fernie, to the south of Lower Arrow Lake, and east of the lower Okanagan Valley, are all restricted to elevations of 3,000 to 4,000 feet above sea level where vegetation is less like that of the surrounding dry regions than that of the bracken belts as outlined. In the moister Revelstoke district bracken was common at the valley level of under 1,500 feet and continued up to an altitude a little above 4,500 feet on Mt. Revelstoke, beyond which the character of the flora became more alpine.

It is a matter of precipitation apparently which sets bounds primarily to these vegetation zones, leaving a Dry Interior of bunch grass, sage brush and yellow pine between a coastal and an inland hygrophytic evergreen forest containing bracken at suitable places. At its driest, in the Okanagan and northwestward from Kamloops, the Dry Interior has less

than 10 inches of precipitation annually. On the coast there are places having well over 100 inches. Precipitation lines (isohyets) after Climatic maps of North America (3) are added to the mapping of bracken and show that at around 20 to 30 inches it appears to reach its limits in most parts of British Columbia. Not only in the dry belts but in all the north away from the coast, and from a little west of the summits of the Rockies eastward across the plains the rainfall is below the figures named and bracken is absent unless, as already intimated, at higher altitudes. The exceptional occurrence mentioned at the Banff Hot Springs, may well be attributable to a locally better watered environment, or it may be accounted for in another way to be referred to later. At about 25 inches again in eastern Manitoba bracken reappears, to become abundant as the eastern provinces with their higher precipitation are reached. Looking farther afield to the moist climate of Ireland and Scotland bracken is also found to be exceedingly abundant. Fenton (7) points out a significant difference in the bracken cover of even the moist west coast of Scotland and the drier east coast. Throughout the world, indeed, such a correlation seems to be valid for this cosmopolitan species (or complex of species).

In view of what has been elicited it appears just a bit anomalous that bracken should be, as proves to be the case, definitely selective of the drier habitats available within its range. In the lower Fraser Valley, where it was under closest observation, it is characteristically a benchland species. On lower land it was observed repeatedly occupying the knolls only of undulating ground. On the delta lands, formed in recent geological time at the mouth of the Fraser River, and on comparable soils, as mapped by Kelley and Spilsbury (12), at Pitt Meadows, Matsqui Prairie, etc., all within the general area of heavy precipitation, bracken is absent except under certain special conditions to be given consideration. Eastern Canadian observations largely support these findings.

The sort of situation in the low bracken-free areas on which a certain amount of the fern may appear are most often artificial embankments for roads or railways. Earth thrown from ditches and even the shoulders of ditches may also carry it. For mile after mile the banks of the narrow channels skirting Rosebank Island were more or less fringed with bracken, whereas few specimens were seen on the drive across the island. In each case better drainage conditions have been created than those prevailing all around. In places where delta lands or islands consist of gravelly instead of clay deposits bracken thrives. In other instances a grove of trees or even a larger tree among bushes is found to harbour the only bracken to be seen, the inference being that trees also can drain the soil of immense quantities of excess water. Certain heavily infested peat lands on the delta appeared to remain as exceptions to what was otherwise the rule. Only a few of these were explored and only at the last, a few miles from Steveston, did it become apparent from a hole left by recent removal of peat that the water table can drop to leave an ample depth of the dry sphagnous material for the rooting of the bracken present. This condition probably obtains for only a part of the year but while it lasts will be in marked contrast with the permanently restricted sub-drainage of the surrounding alluvial soils. Where precipitation is as heavy as it is in even the least watered of this region any difference in natural drainage between



the Recent Delta, where bracken growth seems inhibited, and the remainder of the country may well be significant. Apropos here is some discussion by Fenton (6) based on Scottish experience: "Physical conditions may at times defeat the progress of this plant. The raising of the water level of the soil above a certain level undoubtedly is very detrimental to survival. This fact was seemingly recognized and made more use of in the past than at the present time; judging from the writings of McTurk (1837) and Murray (1837). On the other hand the draining of certain parts has been blamed for assisting the plant to spread, but there seems little definite information on this point. On very dry soils which have also a rather dry subsoil bracken does not show to great advantage. . . . "

Granting that adjustment of water level may often be essential for the presence of bracken, the question remains as to what effect of drainage is vital. Does the removal of excess water merely provide better soil

aeration with possible encouragement of a congenial soil microflora and microfauna, or is there a making available of compounds essential to, or a leaching out of substances inimical to the growth of bracken?

Analyses of soils, feeding stuffs and even bracken samples from various parts of the delta and upland by the Dominion Chemist (15), and by workers at the University of British Columbia (11) and the British Columbia Department of Agriculture (5) have shown less striking differences than might have been anticipated. If any significant mineral deficiency or excess of a nutritional nature is involved it has not yet been clearly established.

One of the outstanding effects of precipitation in any climate is registered in the movement of the salts in the soil. With scanty rainfall and high evaporation there is a concentration of these in the upper soil horizons. In wet climates the tendency is to leach out these salts and leave a condition of acidity. In the present case both bench lands and the badly drained lowlands are acid; according to Kelley and Spilsbury's studies "the only instance of a neutral or basic horizon in the lower Fraser valley" is an underlying horizon in the Langley clay loam of which the surface is markedly acid. It is doubtful whether the analyses provided any satisfactory comparison of the better drained oases supporting bracken and the rest of the delta land, or of higher land in general and those parts having faulty drainage owing to hard pan beneath. This much, however, is revealed by the findings: "the presence of comparatively large amounts of essential minerals in these (zonal) soils shows that solubility of salts and bases must be slow." If the same is true of delta soils, leaching would be even less rapid and therefore hardly adequate to account for the prompt advent of bracken to drained situations.

Much of the literature concerning bracken assumes its partiality for acid soils and its intolerance of lime, and liming has been frequently recommended for its suppression. While its broader British Columbian distribution conforms well with high soil acidity (which are also heavy precipitation) zones, and its isolated occurrence within the probably acidifying influence of the sulphur springs at Banff may also be taken into account, the fact remains that the growth of this fern is inhibited in the Recent Delta lands notwithstanding their acidity. While acidity as a concomitant of poor drainage may not be strictly comparable with that resulting from leaching, it apparently is not acidity per se which is the differential in the situation. Instances could be brought forward, too, of soils underlain by limestone and freely supporting bracken. On the Aylmer plains near Ottawa its rootstocks have been found resting directly on limestone strata. However, determinations by the Division of Chemistry, Science Service, of the pH values of soil samples from this location indicated slight acidity, most marked on the shallowest soil, and somewhat alkaline from deeper soils bordering the outcrop of rock and not carrying bracken.

Beyond this it is perhaps unprofitable to go until more ample data are available. If this plant is calciphobous that fact might be taken to indicate removal of an amount of lime excessive for it, but according to experiments quoted by Weaver and Clements (17), "Calciphobous species such as the common brake *(Pteris aquilina)* also flourish in a soil rich in

lime provided other salts are not in excess." Similarly, lime unaccompanied by a large amount of soluble salts has been found to stimulate such a weed of acid soils as sheep sorrel up to the point where more useful plants benefited also enough to compete with it (2). From what has been stated about these Fraser Valley soils it would not appear that this is the situation prevailing. The advent of bracken to sites enjoying better drainage than before is probably due to other amelioration of the environment accompanying drainage.

The temperature relation is important in the growth of plants and could exert an influence favourable to bracken with drainage, but no evidence was collected to show this operative here. Climatic temperatures are rather uniform: "The mean annual temperature at different stations shows a variation of only two degrees in different parts of the valley" (12).

The light relation of bracken would not enter into the problem of its general absence from the delta soils, although an instance can be cited of its suppression by increasing shade in a grove near Ladner in which, eight years earlier, its drainage requirements seemed to be provided for by the water demands of the trees. Bracken now persists chiefly as a fringe outside the grove. Quoting Fenton (6) again "There is little doubt that rather open woodland is the original home of bracken . . . . Where trees cast too dense a shade the plant becomes weakly and dies out".

Briefly then, it would appear that bracken is definitely related to *(a)* a moist climate with precipitation of around 20 inches or more, and with the acid reaction of soil ordinarily associated therewith, but with the acid relation somewhat involved; *(b)* well aerated, rather open type of soil, or heavier lowland soils and situations only if adequate drainage is secured; *(c)* light at least better than that of dense woodland.

REDWATER INCIDENCE

Outside the lower Fraser Valley some redwater disease has been reported under similar climatic, drainage and vegetation conditions in parts of Vancouver Island, also (1) on islands off the mainland, at Terrace in the Skeena River district and in the Glen Devon district on the west side of Upper Arrow Lake. Potential redwater territory may well be much more extensive in the wet belts but owing to absence of cattle over so much of it this potentiality does not become apparent. It does extend southward into Washington and Oregon. Some checking, far from complete, of other countries reporting redwater disease is suggestive of correlations similar to those found here.

Within the lower Fraser Valley the zonation for redwater disease is well known to be closely that which has been shown for bracken. Almost throughout the Recent Delta, or at altitudes up to about 25 feet above sea level the trouble is practically unknown. At about 25 feet altitude near Chilliwack are a number of farms with definite redwater history, and in each instance with enough drainage somewhere within its bounds to admit bracken. Some of these farms were shown to have an open gravelly subsoil. On most of them the bracken occurring is on gullied or irregular land which provides a measure of drainage lacking on the general level. The situation may be described as borderland between delta and bench-

land. On the higher Raised Delta and Upland sections of the Fraser delta region good drainage is not so often lacking and bracken is a regular feature of idle land. Redwater disease is not uniformly present throughout this more elevated territory, and up to the present surveys have failed to find any satisfactory explanation of this irregularity. Adjoining farms which would be considered comparable in every respect maintain this one point of difference over many years. In one such instance the hitherto clean farm has at last reported its first cases of the disease. More often a farm with an early redwater history has become and remained free of trouble. Many farmers hope, as they outgrow pioneer conditions, to become free of it. It is no part of the present purpose to consider the various theories which have been advanced to account for redwater disease, but it is thought that there are transitional features about the situation around Chilliwack that might be worthy of further study.

Until such time as there is something more tangible toward which to direct an attack it would appear to be a reasonable policy to look for ways of fitting practise to the facts of the case. In some instances owners of cattle have disposed of them in favour of a less precarious investment, but it is not always feasible to make so drastic a change. Favourable access to dairy or livestock markets may counsel continuance in the face of the degree of loss entailed by the disease. The intensive use for truck farming or gardening of many areas free of redwater may impede an otherwise logical shift of livestock and dairy production to such lands. Nevertheless, after due consideration of the economics of the situation, some adjustment of land use would seem to be indicated.

CONCLUSIONS

The bracken of British Columbia, *Pteridium aquilinum* (L.) Kuhn var. *lanuginosum* (Bong.) Fernald, ranges north and south of that area but practically stops short of the crest of the Rocky Mountains eastward. The bracken occurring from the Atlantic westward to eastern Manitoba is considered to be another species *Pteridium latiusculum* (Desv.) Hieron. Little, if any, of either occurs on the intervening plains.

Within British Columbia bracken is found in two main belts, one coastal, the other, roughly parallel between the Dry Interior and the Continental Divide. Records outside these belts are all at altitudes of 3,000 or 4,000 feet with vegetation more nearly that of bracken territory elsewhere than of the immediate region, and indicating hygrophytic zonation.

Bracken distribution appears to be restricted to regions with an annual precipitation of around 20 inches or more, but within such a region is selective of the better drained sites. On the poorly drained Recent Delta of the lower Fraser River the fern is absent except where the water table is lowered by natural or artificial drainage.

In general, regions of high precipitation have acid soils which are usually considered to be congenial to bracken. Soils in the lower Fraser Valley are acid throughout but support bracken only where some undetermined effect of drainage is operative. The evidence from soil surveys is

that solubility and consequent leaching of mineral salts and bases, some of which might be inimical to bracken growth, is slow and unlikely to be the significant factor.

The rather striking appearance of an association between redwater disease and bracken in the lower Fraser valley, elsewhere in British Columbia and in at least some other countries, must be viewed in the light of the fact that cattle in other bracken territory, i.e., in all of eastern North America, have never been known to be affected. Such differences as there are in the associated flora and in bracken itself in various regions, or in the flora of Fraser Valley upland and lowland, have not yielded correlations that would seem significant in relation to redwater.

ACKNOWLEDGMENTS

To Mr. W. H. Minshall credit is due for preparation of the map from the data. Other officers of the Dominion Department of Agriculture and of the Provincial Government of British Columbia have given valued assistance in carrying out the surveys, in securing information or in critical reading of drafts of the manuscript.

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METHODS AND RATIONS FOR FATTENING POULTRY[1]

VI. THE COMPARATIVE ECONOMY OF RANGE REARING, CRATE FATTENING AND CAPONIZING FOR PRODUCTION OF ROASTERS

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The comparative efficiency of the various practices designed to improve the market quality of stock is, in the final analysis, secondary to the economy of their action. While certain methods of fattening for market are definitely more efficient than others it becomes necessary to balance their increased efficiency against the cost of their application. In connection with a series of experiments on methods and rations for fattening poultry the present cost analysis has been made.

MATERIALS AND METHODS

Part of the data shown herein was obtained from a fattening test previously reported (*2*). This particular test was chosen for several reasons, firstly because an excellent but not unusually high response to fattening treatment was obtained, and secondly because the test was controlled by a group of related cockerels which remained under the usual range conditions, data from which were valuable as a standard for comparison of treatments. These data were further supplemented by unpublished data on capons, which, while taken from related birds during the same period as the above mentioned test were not actually a part of that experiment. For purposes of reference it should be stated that the data used were those of group B (crate fattened) which received ground yellow corn including 10% beef fat as a fattening mash, and group E which were kept on range, complete detail of both of which may be seen in the publication referred to above (2). The range group considered in this analysis had adequate range on alfalfa fields and received scratch grain night and morning with a growing mash mixture available in hoppers at all times. The gains recorded are from starved weight to starved weight in all instances with the exception only of those of the capons. In calculating feed costs for both the range cockerels and capons a consumption of 2 parts of grain to 1 of mash was used as being a satisfactory approximation to usual conditions. On the crate fattened and range fed birds actual commercial gradings were available, while for the capons the condition of fatness as accurately determined by a method of sampling previously reported upon (1) plus the appearance of the dressed carcasses were used as the basis of an estimate of grading.

The feed prices quoted are actual as are also the dressed poultry prices which were those being paid to country shippers at the time of the experiment. In this connection it should be noted that all gradings were made on a commercial basis exclusive of the degrading effect of skin tears, too many pin feathers, etc. which are under the control of the producer. The

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TABLE 1.—COSTS AND RETURNS ON CRATE FATTENED COCKERELS, UNFATTENED COCKERELS AND CAPONS

Treatment	Gain in 2 wk.	Feed consumption		Feed cost		Value of gain			Profit over feed cost	Profit due to crate feeding or caponizing	Average feed consumption to 7 lb. weight	Feed cost to 7 lb. weight	Value of dressed birds at 7 lb. weight	Profit over feed cost	Total profit over feed cost at marketing
		Mash	Milk	Actual	Per lb. gain	Weight gained	Increase in grade	Total							
	lb.	lb.	lb.	cts.	cts.	cts.	cts.	cts.	cts.	cts.	lb.	cts.	cts.	cts.	cts.
Crate fattened cockerels	1.21	4.21	4.41	8.37	6.92	19.36	11.89	31.25	22.88	23.82	39.00	76.00	112	36.0	58.9
Range fed cockerels	0.42	4.14	—	7.66	18.24	6.72	—	6.72	–0.94	—	39.00	76.00	112	36.0	35.1
Capons	0.31	3.90	—	7.21	23.25	4.96	10.78	15.74	8.53	4.47*	35.00	68.00	112	44.0	48.5

* Charge of 5 cts. per bird deducted to cover cost of caponizing.

Costs allowed for various feeding stuffs:—ground yellow corn 1.5 cts. lb.; beef fat 2.5 cts. lb.; skim milk 0.20 cts. lb.; starter mash 2.75 cts. lb.; growing mash 2.25 cts. lb.; scratch grain 1.65 cts. lb.

Calculated value for dressed carcasses: Grade B—16 cts. lb.; Grade A—18 cts. lb.

grading allowed therefore is the best that could be obtained and presupposes great care on the part of the producer in proper killing and handling of the dressed birds. The feed consumption to 7 lb. weight or to the commencement of fattening is taken from extensive data on cockerels and capons published in mimeographed form from this Division. No attempt has been made to calculate labour, equipment or interest costs in this work since they vary over such a wide range and should be estimated by each individual operator in the light of his own circumstances. It should be pointed out that crate feeding involves crates, but since they are commonly satisfactorily made of waste or very cheap lumber they do not constitute a heavy cost.

RESULTS

Table 1 is a summary of the cost data obtained. One of the main features is the relatively poor gain of the range fed birds. This may to a large extent be due to a relatively large requirement of feed to maintain activity and body temperature under range conditions in this latitude.

Considering feed consumption, it will be noted that this was very similar for all three classes. The slightly lower consumption of the capons is in line with their lower gain and the decreased activity characteristic of capons as a class. The fluid skim milk fed to the crate fattened birds had little effect on the total consumption of that group if considered on a dry matter basis (10% dry matter).

Summing up the matter of gain and feed consumption the results are largely explained by a consideration of three factors namely, temperature, activity and suitability of feed. Under crate fattening conditions temperatures are moderate, activity is reduced to a negligible quantity, and feeds are given in palatable form and of a nature calculated best to increase gains, particularly of fat. Hence the results of crate fattening as indicated by these data are large gains on moderate feed consumption. On range, on the other hand, temperatures are low, activity is great, and gains are relatively small even on heavy feed consumption because of the large demands for maintenance of body temperature and activity. The higher requirement of feed to maintain temperature under cold conditions without activity but with good fattening feeds has been reported in a previous publication (3) and the figures here shown suggest the further importance of the activity factor.

It was presumed that all stock before fattening would on the average be grade B which is approximately the case since very few birds would be sufficiently fat to enter A grade. In any case this treatment is comparable for all groups. The much greater return for the crate fed birds was due to their large gain and improvement in the grade of the carcass. An increased price of 2 cts. per lb. is paid for grade A roasters over grade B. Since the range fed group contained 19.4% grade A birds whereas the crate fed birds had 94.4% of this grade, the former was subtracted from the latter and the residual percentage was multiplied by 2 cts. to obtain the rate in cents per pound which must be applied to the final dressed weight of the birds to determine the additional value brought about by increase in grade. Since it is impossible to grade the birds at the beginning of the 2-week period, the acceptance of the 19.4% of grade A birds as the basic standard becomes

necessary. An increased value per bird through superior grading of as high as 11.89 cts. in 2 weeks' fattening is the net result of the fattening process, which when added to the value of the weight gained becomes 31.25 cts. per bird for this fattening period. The range cockerels had on the average 43.7% of fat in the area of the main breast feather tract whereas the capons had 59.58% and the crate fattened cockerels 63.58%. It has been previously reported (1) that the percentage of fat in a sample from this area is an excellent guide to the fatness of the whole carcass and particularly to the skin and subcutaneous fat which is of the greatest importance in obtaining a high grading. An examination of the dressed carcasses in conjunction with the percentage of fat of the capons indicates that with possibly one exception all birds amongst this group or 94.7% were capable of entering A grade, making a net valuation of 1.51 cts. per lb. for increased grading over the range group. In addition to the degree of fatness there was a satin-like finish to these birds which made a very attractive appearance and enhanced their grading quality. The increased softness of skin was readily apparent when sampling as the skin offered practically no resistance to the sharp scalpel whereas even with the crate fattened cockerels the keen edge of the blade was quickly lost after cutting a relatively few samples. The capons were therefore much superior in grading to the range cockerels and were credited with a total of 15.4 cts. per bird for the value of the gain made in the 2-week period and for the improvement in market quality.

Returns from 2 weeks of fattening after deduction of cost of feed amounted to 22.8 cts. per bird. There was a net loss of 0.94 cts. per bird on range making the total additional profit over the range group due to crate fattening to be 23.8 cts. per bird, a substantial amount. For capons over the 2-week period the net profit attributable largely to their native quality was 4.47 cts. per bird after allowance was made for the cost of caponizing at 5 cts. per bird.

Apart from the improved financial returns it is of more than passing interest to know the feed cost to raise cockerels and capons to time of fattening, or 7 lb. weight in this instance, and to calculate the net returns on the whole operation from hatching to marketing. These figures are shown and when added to the profit for the gain for the 2-week period indicate a net return of 58.9 cts. per bird under crate fattening treatment, 35 cts. per bird if killed off range, and 48 cts. per bird for capons. It will be noted that since less feed is required to raise a capon to 7 lb. weight than for cockerels, owing without doubt to the relative docility and inactivity of the former, the capons compare vary favourably with the crate fattened cockerels. The actual profit return must be further reduced in all instances by the actual or calculated costs of the original chicks.

DISCUSSION

The above reported data throw some light upon the economics of crate fattening, caponizing and range rearing when preparing stock of roaster age for market.

Range Rearing for Market

Considering the killing of birds directly off range for market, it is apparent that during the last 2 weeks prior to killing the gain may be so

small as to be less in actual value than the cost of feed. Where conditions make it impossible to caponize or crate feed it is of interest to note that over the whole rearing period a profit over feed cost of 35 cts. per bird is recorded for range fed stock.

Crate Feeding for Market

The data presented indicate very definitely that crate feeding is productive of the greatest gain at moderate feed cost and of very much higher quality dressed birds than can be produced by range feeding. The cost of the crate feeding equipment and the time involved are greater for this method, however, and must be charged against the greater profit of 10.4 cts. and 23.8 cts. per bird over caponizing and range feeding respectively according to the individual operator's equipment costs and evaluation of time and labour involved. The actual comparative efficiency of the three finishing operations is probably best indicated by the profit over feed cost of 22.9 cts. per bird for crate fattening, of 8.53 cts. for caponizing, and the loss of 0.94 cts. per bird from range feeding. Under conditions where no definite premium is paid for quality of the dressed bird, crate feeding, of course, would be relatively unprofitable, but under Canadian conditions where a definite price differential exists for quality, crate feeding represents the means to the greatest actual return in preparing for market.

Caponizing

In this analysis caponizing has proven to be exceeded only by crate fattening in results obtained. When factors such as lack of accommodation make crate fattening impractical caponizing may be the best method of obtaining the greatest returns. The cost of caponizing has been charged at 5 cts. per bird which is the usual charge. Many operators, however, quickly learn to caponize efficiently under which conditions the net return through caponizing would be higher to the extent of this charge. Briefly therefore, it may be stated that the advantages of the capon are that they can run with the pullets, which is not the case with cockerels; they require less feed to reach a given weight; they are almost as fat as well crate fattened birds even when killed off range; and they may be expected to show a much greater profit than cockerels left on range to killing time, and may even closely approach that obtainable from well crate fattened birds.

All things considered, it is safe to say that caponizing as a means to the profitable production of quality stock should be the principal competitor of crate feeding and have much wider application than is at present the case.

In using the data for profit over feed cost, it should be borne in mind that the original cost of the chick, depreciation on housing and equipment, interest on investment and labour costs have not been considered.

SUMMARY

An investigation into the efficiency and costs of production of market poultry of the roaster class by three methods, namely, crate fattening, caponizing or killing off range, has shown the following:—

1. Crate feeding was the most efficient method and was productive of very high quality stock. A total profit over feed cost of approximately 59 cents per bird was shown for this method of finishing. The extremely high efficiency of the fattening period was evidenced by a feed cost per pound of gain of 6.92 cts. for the crate fattened birds as against 18.24 cts. and 23.25 cts. for the range cockerels and capons respectively.

2. Caponizing for market was the next most efficient method and was very economical because of the lower feed requirement of capons during the rearing period and on account of their relatively high degree of fatness even when killed off range. A total profit over cost of feed of 48 cts. per bird after deducting the cost of caponizing was realized in these tests.

3. Killing of cockerels for market directly off range was the least economical procedure in that gains were low and at a relatively high feed cost and market quality was such as to draw a much lower market evaluation than either crate fed cockerels or capons. A total profit over feed cost of 35 cts. per bird was shown for these birds.

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THE DISINFECTING VALUE OF FUNGICIDES USED FOR TREATING CEREAL SEEDS AND THEIR INFLUENCE ON GROWTH[1]

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INTRODUCTION

Beneficial effects from the treatment of cereal seeds with organic mercury fungicides have been reported by Simmonds (15), Simmonds and Scott (17), Christensen and Stakman (1), Machacek and Greaney (6), Crosier (2), Hynes (5), and Scott (14). All of these investigators reported a reduction in seedling blight following treatment of diseased seed or of healthy seed sown in diseased soil. They concluded that the fungicides destroyed seed-borne fungi and gave some protection from soil fungi during the early stages of seedling growth. Any infection that occurred at a later stage in the growth of the plants from diseased seed was considered, apparently, to have come from the soil or other outside sources. No mention was made of the possibility of seed-borne parasites being left unaffected by the fungicide and of later infecting the seedlings. Hynes (5) referred to the work of a number of investigators who were of the opinion that treatment of seed with hot water, or organic mercurials in solution or in dust form did not always eliminate the seed-borne fungus (*Helminthosporium sativum* Pamm. King and Bakke) completely, but retarded its development so that increased emergence and vigour of seedlings resulted. The results of some preliminary work done at this laboratory (10) indicated that the fungus *H. sativum* which had become well established in barley kernels, although definitely inhibited by treatment with New Improved Ceresan, had not been entirely destroyed. Under suitable conditions, it revived, after a certain period. The revival was largely dependent upon temperature.

The occurrence of lesions caused by *H. sativum* on maturing cereal plants, the seed of which had been treated with organic mercury fungicides, has been studied by various workers. Hynes (5) found that none of the five fungicides which he used afforded any protection against footrot and rootrot development in wheat plants in the adult stages. Machacek and Greaney (6) reported that in experiments conducted in naturally infected soil in 1932, 1933, and 1934, mature plants had a lower disease rating if the seed were treated with certain organic mercury fungicides. The same authors reported (7) the results of experiments conducted in 1935–37 with diseased wheat seed. They found that disinfection of the seed with organic mercurials in the form of dusts prevented kernel decay in the soil, increased seedling emergence, prevented seedling blight and usually resulted in marked increases in yields. The seed disinfection did not, however, protect plants in the more advanced stages of growth from becoming attacked by rootrot fungi occurring in the soil. Christensen and Stakman (1) found that treatment of diseased lots of barley with Ceresan resulted in improved stands and often in increased yields.

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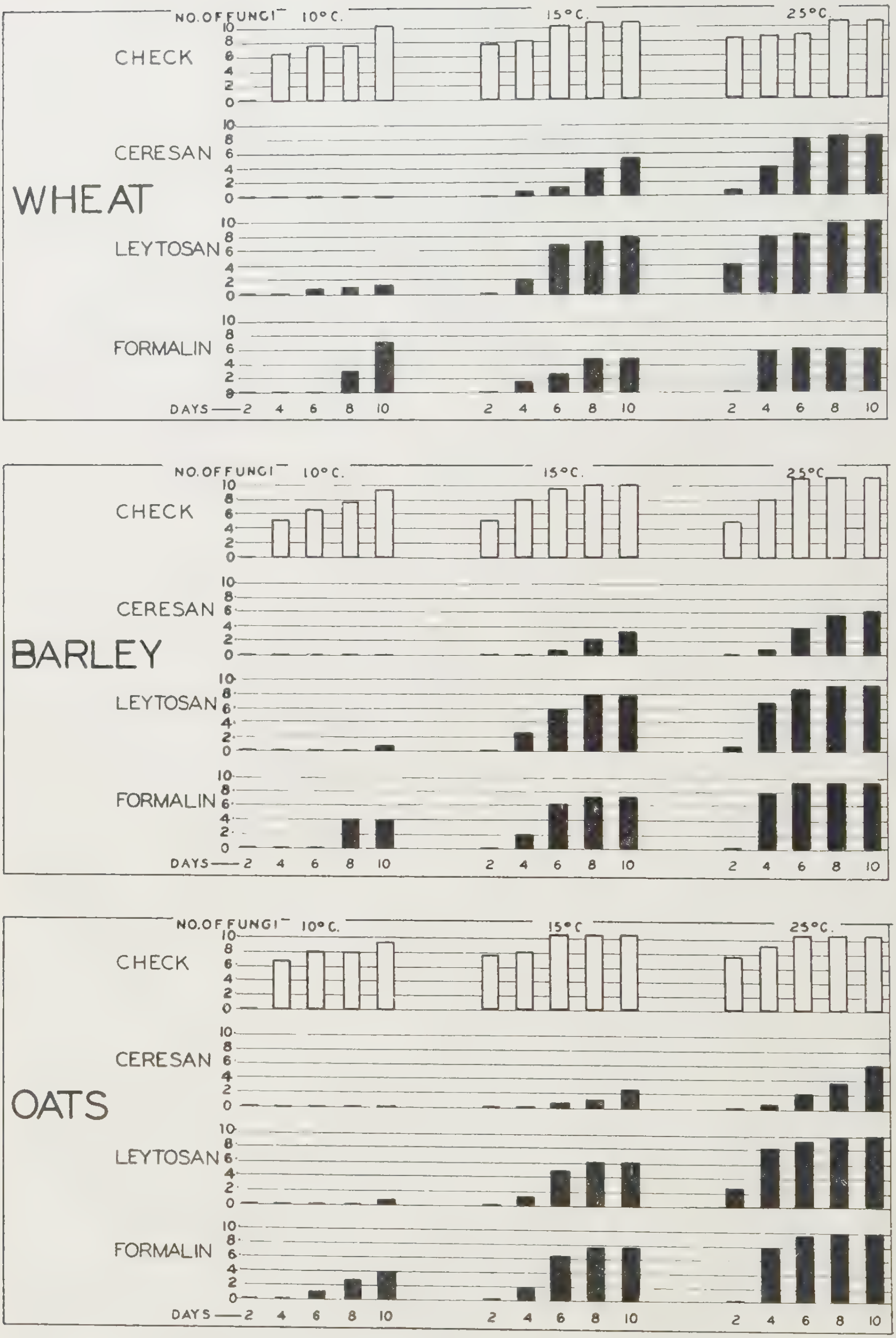

FIGURE 1. The number of fungi developing from treated and untreated kernels of wheat, oats, and barley, incubated on agar at 10° C., 15° C., and 25° C.

The effect of temperature on the growth and infective powers of cereal rootrot fungi such as *H. sativum*, *Fusarium culmorum* (W. G. Smith) Sacc. and *Gibberella saubinetii* (Mont.) Sacc., has been studied by Dosdall (4), Dickson, Eckerson and Link (3), McKinney (8), Sallans (12), Scott and Sallans (13) and Simmonds (15). These investigators have shown that temperature may influence the growth both of fungus and host.

THE RELATION OF TEMPERATURE TO THE DISINFECTANT VALUE OF SOME FUNGICIDES USED ON CEREAL SEEDS

In this experiment, field samples of Mindum wheat, Hannchen barley and an unknown variety of oats were used to test the effect of three fungicides on any internal fungi that the seed might be carrying, and to relate this effect to temperature. The fungicides were New Improved Ceresan, Half Ounce Leytosan and formalin. They were applied according to the manufacturer's directions and the treated seed was stored in open envelopes at room temperature (65 to 70° F.) for a week. Untreated portions of the samples were rinsed in sterile water, dried rapidly and stored in the same way. This was an attempt to remove any fungus spores and fragments of mycelium which might be on the surface of the kernels and probably would be destroyed by the fungicides which were used on the treated lots. The kernels were plated on acidified potato dextrose agar (pH 6.0), with 8 kernels per plate. The cultures, in triplicate, were incubated at 10°, 15° and 25° C. For comparison, the temperature of the soil at seed level at Muenster, Sask., during May, 1935, ranged from 0° C. to 24° C. and the mean daily temperature was 10° C. This represents fairly well the conditions in the central part of Saskatchewan during that period.

Records on the number of fungi developing from the seed were kept daily for 10 days. The data which were taken on the 2nd, 4th, 6th, 8th, and 10th days are shown graphically in Figure 1.

Fungi developed so rapidly on the untreated kernels of the three cereals at 15° and 25° C. that over 75% bore colonies on the second day and all had colonies growing from them after 4 days of incubation. After the fourth day additional fungi appeared with the result that some kernels produced 2 or 3 kinds of fungi. Fungus growth was slower at 10° C. but it soon equalled the number of colonies observed at the higher temperatures.

The development of fungi from the treated kernels was delayed and reduced by the fungicides, particularly at 10° C. At that temperature, no fungi grew from any of the kernels treated with New Improved Ceresan during the entire period of incubation. At the end of that period a few had developed on kernels that had been treated with Half Ounce Leytosan and about 50% of those treated with formalin were producing fungi. At 15° C. fungus growth from the kernels was sharply depressed for 4 days by the 3 fungicides. After that period a considerable number of the kernels treated with the Leytosan dust or formalin developed colonies of fungi while fewer of the kernels treated with New Improved Ceresan produced fungi. At 25° C., which is a much higher temperature than that of the soil during seedling growth in Saskatchewan, fungus development was checked by seed treatment for 2 days. After that time fungi developed freely from all of the treated kernels except barley and oats treated with New Improved Ceresan; growth from these was noticeably reduced (Figure 2).

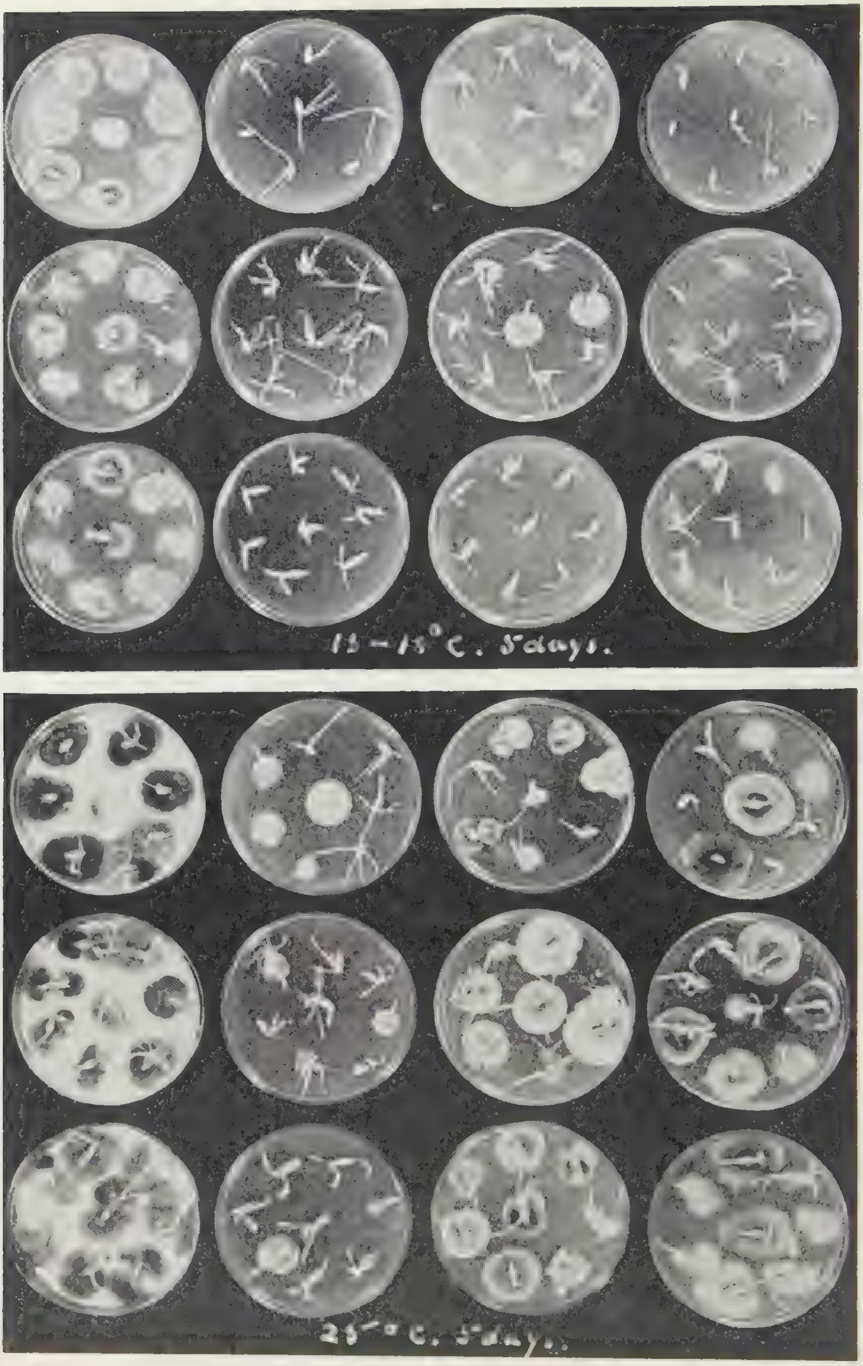

FIGURE 2. Two series of agar plate cultures showing the influence of temperature and fungicides on the development of fungi from cereal seeds. The upper 12 plates were incubated at 15° C. to 18° C. and the lower series at 25° C., both for 5 days. In each case the horizontal rows from top to bottom represent wheat, barley and oats, while the vertical rows from left to right are check, New Improved Ceresan, Half Ounce Leytosan and formalin treatments.

The results indicate that the effectiveness of the fungicides used on the 3 seed grain samples was influenced by temperature, and that some seed-borne fungi survived seed treatment, although their development was delayed. The number of fungi which would develop from other seed samples might be quite different, because the depth of penetration of the seed coat by fungi of various kinds differs greatly (16) and depends partly upon the stage of development at which kernels are infected (11). These differences, in addition to variation in the number of infected kernels in samples, and in methods of treatment, are sufficient to explain apparently contradictory results obtained by different investigators.

The delay in growth of fungi caused by a fungicide is important in the development of a wheat seedling. If the plant has a chance to establish vigorous growth, it may escape serious infection by fungi from the seed or soil. The effect of a fungicidal treatment at various temperatures on the germination of wheat seed and fungal development from the kernels on agar is illustrated in Figure 3. It shows that germination proceeded in

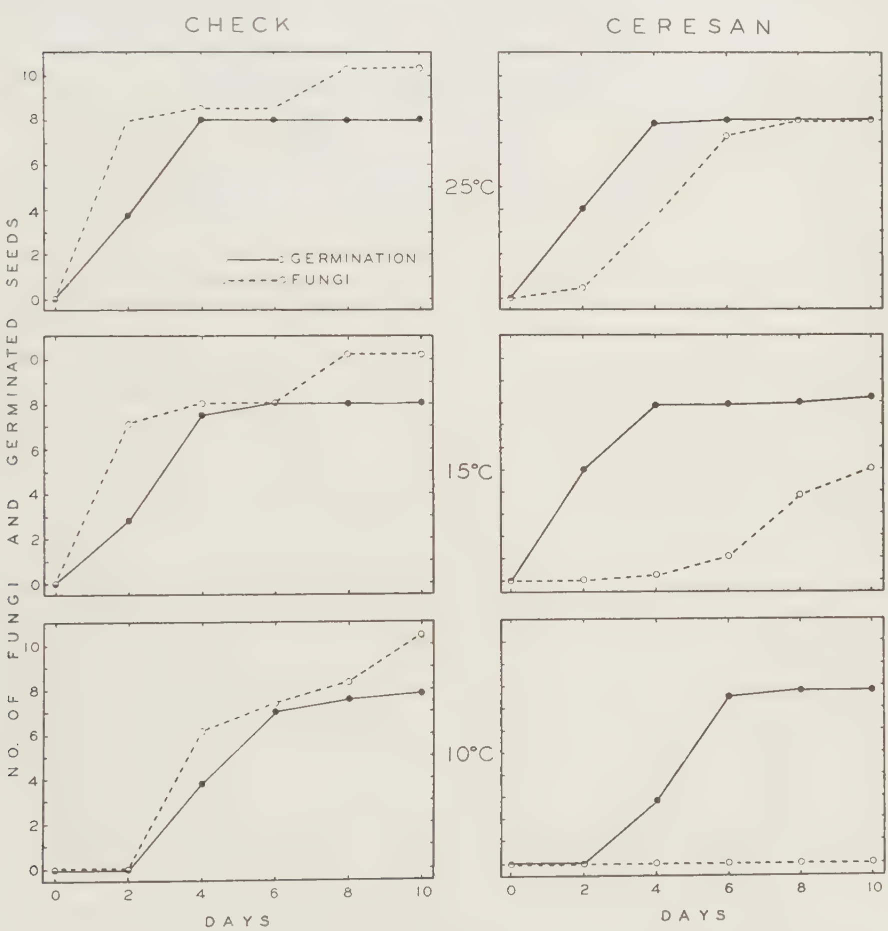

FIGURE 3. Showing the relationship between temperature and the influence of New Improved Ceresan on the germination of wheat seed and fungal development from the seed. The wheat was germinated on potato dextrose agar.

a regular manner on agar at 10° C. which is near the temperature of the soil at the time of seeding wheat, while fungus growth was prevented entirely for ten days by New Improved Ceresan, but was vigorous where no treatment was used. As the temperature was increased, the difference between the speed of germination and the growth of fungi became less.

THE EFFECT OF CERTAIN SEED TREATMENTS AS DETERMINED FROM FIELD RESULTS

For the first experiment, samples of seed wheat from 12 farms located in various parts of Saskatchewan were used. These samples were examined carefully in the laboratory for the presence of fungi and it was found that 2 of them, numbers 2 and 9, were lightly infected with *H. sativum* while the others were relatively free of pathogenic fungi. Each sample was divided into 4 lots, 1 of which was left untreated, the others treated with New Improved Ceresan, Half Ounce Leytosan and formalin respectively, with the regular dosages. The experiment was sown at Scott, Saskatoon, and Indian Head in randomized blocks. Each block consisted of 48 plots separated by single untreated rows. A plot contained 2 rows 1 rod in length sown 6 inches apart, and approximately 300 seeds were sown in each row. The seeds were not counted but weighed carefully after the mean weight of 5 lots of 300 seeds had been found for each sample. Emergence data were obtained at Saskatoon and Indian Head, and yield data from all 3 locations. These data are presented in Table 1 as totals of the 2 plots (4 rows) at each of the locations.

TABLE 1.—A SUMMARY OF THE EMERGENCE AND YIELD OF 12 FARM SAMPLES OF WHEAT WHICH HAD BEEN TREATED WITH FUNGICIDES TO CONTROL COMMON ROOTROT

Sample No.	Emergence					Yield of grain				
	Check	Ceresan	Leytosan	Formalin	Total	Check	Ceresan	Leytosan	Formalin	Total
	Number	Number	Number	Number	Number	Grams	Grams	Grams	Grams	Grams
1	803	801	801	489	2894	1696	1789	1662	1286	6433
2	776	813	816	617	2972	1845	2014	1866	1469	7194
3	868	874	877	577	3196	1717	1884	1756	1267	6624
4	807	851	826	464	2948	2063	2227	1977	1093	7360
5	747	765	792	479	2783	1791	1729	1925	1295	6740
6	792	791	815	601	2999	1737	1742	1711	1398	6588
7	805	845	815	563	3028	1760	1816	1872	1292	6740
8	860	893	890	726	3369	1706	1937	1965	1434	7042
9	754	793	779	573	2899	1730	1788	1850	1160	6528
10	841	809	854	599	3103	2001	2167	1950	1427	7545
11	759	704	741	538	2742	1726	1805	1807	1493	6831
12	871	850	830	578	3129	2059	2163	1848	1309	7380
Total	9633	9789	9836	6804	36062	21831	23061	22190	15923	83005

The results indicate significant differences between the emergence of the 12 samples, but the differences between their yields were not significant. The difference in germinability is reflected again in the different reaction of the various samples to treatment; this is shown by significant treatment × samples interactions in both emergence and yield. The type of soil

TABLE 2.—ANALYSES OF VARIANCE OF DATA SUMMARIZED IN TABLE 1

——	Emergence counts		Yield of grain	
	Degrees of freedom	Mean squares*	Degrees of freedom	Mean squares*
Between plots	47		71	
Locations	1	**15426**	2	**963021**
Blocks	1	1242	1	25
Samples	11	**1949**	11	5438
Locations × samples	11	498	22	5830
Error I	23	642	35	5949
Within plots	144		216	
Treatments	3	**46151**	3	**147371**
Treatments × samples	33	**3528**	33	**2471**
Locations × treatments	3	**16140**	6	**43857**
Locations × treatments × samples	33	**220**	66	**1975**
Error II	72	97.5	108	618.6

*Mean squares in bold face type exceed the one per cent point of significance.

TABLE 3.—EFFECT OF TREATING SEED WITH NEW IMPROVED CERESAN ON PLANT EMERGENCE, ROOTROT DISEASE RATING AND YIELD OF CHARLOTTETOWN NO. 80 BARLEY. THIS SAMPLE OF BARLEY CARRIED *H. sativum* ON 95% OF THE KERNELS

Days after planting	Treatment	Plant emergence	Disease rating	Dry weight	Yield
		%	%	Gm.	Gm.
14	None—control	39.0	24.1	2.6	
	N. I. Ceresan	94.0	1.5	5.0	
28	None—control		31.8	28.2	
	N. I. Ceresan		8.9	49.9	
42	None—control		29.8	109.2	
	N. I. Ceresan		10.8	223.2	
80	None—control		32.4	442.5	95.0
	N. I. Ceresan		11.8	823.5	204.0

and soil conditions apparently affected the response of the samples to treatments. This is indicated by significant locations × treatments × samples interactions. There are highly significant differences as the result of treatment, which are due chiefly to the significant reduction in emergence and yield by formalin. The reduction in yield is greater than one would expect from the observed emergence; this is due to the arrangement of the experiment, where 2 rows of wheat treated with formalin were flanked by 2 untreated rows. Under these conditions, the untreated rows benefited by the reduction in stand of 2 treated rows and prevented the plants in the latter from making up losses in stand by increased tillering, as they ordinarily do where neighboring plants also originate from treated seed. The 1 and 2% increases of emergence by New Improved Ceresan and Half Ounce Leytosan are not significant, nor is the small increase in yield by the latter. However, New Improved Ceresan increased the yield of all but one of the samples and the total increase appears significant.

In the second experiment, a sample of barley carrying *H. sativum* on 95% of the kernels was sown in a field plot in replicated rows 1 rod long and 6 inches apart in the form of a Latin square. One-half of the rows were sown with seed treated with New Improved Ceresan and the others with untreated seed. After the emergence data had been taken the plants in the treated rows were thinned out to correspond to the number in the untreated rows. Data on emergence, rootrot and yield are presented in Table 3.

The results in Table 3 indicate that treatment of a diseased seed sample of barley with New Improved Ceresan improved the stand and increased dry weight and yield, by reducing the amount of disease throughout the season. These results are in sharp contrast with those of the previous experiment where the seed samples were quite free of disease, and the improvement due to treatment with New Improved Ceresan was much smaller.

DISCUSSION

Some of the differences in the infection of seedlings of wheat, oats, and barley which occur from year to year, and the apparent failure of fungicidal control, may be due to fluctuations in the temperature of the soil. In the experiment described in the first part of this paper, temperature had a distinct effect on the rate of growth of fungi from treated kernels. Growth was slow or nil at 10° C., faster at 15° C. and still faster at 25° C., but it was always slower and sparser than the fungus development from untreated kernels. This may indicate that the fungicides killed fungus material on the exterior of the seeds but left the internal hyphae relatively uninjured. The fact that fungi did develop from treated kernels when the temperature was favourable supports this view. A treatment which destroys the surface material has considerable value because it gives the seedling a chance to become established before the fungi within the seed are fully revived and capable of attack. This, in itself, is important and would justify the use of a fungicide on seed grain which is known to be carrying parasitic fungi on the surface of the kernels. However, one should not expect complete control of fungi carried internally if the temperature of the soil is high. The delay in development of these fungi at low temperatures in comparison with that of the developing seedlings, may be ascribed largely to temperature, and both host and parasite are affected. If the seed is sown in soil which is at a temperature of about 12° C., conditions are much more favourable for the seedling than for fungi like *Helminthosporium sativum* and *Fusarium culmorum*, for instance, which grow best above 20° C. At the latter temperature, seedling infection may be severe on wheat, mostly because the plants are growing under unfavourable conditions.

The value of treating seed wheat depends upon the condition of the seed as to fungus content, maturity and physical condition, and upon the care used in treatment. Where the seed is smutty, infected with rootrot

fungi, badly discoloured or injured in other ways, increases in stand and yield will probably be obtained by treating according to instructions with an organic mercury fungicide, such as New Improved Ceresan. In regard to the formalin treatment, past experience has shown that it should be done with great care. There is less probability of injury with sound plump seed than with diseased or injured seed (9). This treatment is very useful for oats and barley, however, and these coarse grains should be treated regularly.

SUMMARY

An experiment is described which shows that fungi may develop from cereal seeds which have been treated with certain organic mercury dusts or formalin, and sown on agar. The development is influenced by temperature and to some extent by the kind of fungicide used. It is believed that the growths which appeared were from deep seated infections and that surface borne contaminations were effectively destroyed by the fungicides tested.

A field experiment is described in which 12 samples of wheat which were relatively free of disease, were divided into 4 portions each, 1 of which was sown untreated, the others being treated with New Improved Ceresan, Half Ounce Leytosan and formalin, respectively. Emergence and yield data showed that the samples reacted differently to the various treatments, and that the effects of those treatments were different at 3 locations, indicating a response to soil type and soil moisture. Under the conditions of the experiment, formalin reduced the stand and yield significantly. New Improved Ceresan increased the stand and yield significantly and Half Ounce Leytosan caused a slight increase in stand and yield. In a second field experiment, a sample of barley which was heavily infected with *H. sativum* was divided into 2 portions, 1 untreated, the other treated with New Improved Ceresan, and this was sown in randomized blocks. In this case, the treatment improved the stand and increased the yield by reducing the amount of disease throughout the season.

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